SCIENTIFIC AMERICAN SUPPLEMENT No. 407

Scientific American Supplement, Vol. XVI., No. 407.
Scientific American, established 1845.

NEW YORK, OCTOBER 20, 1883.

Scientific American Supplement, $5 a year.
Scientific American and Supplement, $7 a year.

THE OBSERVATORY OF THE INTERNATIONAL BUREAU OF WEIGHTS AND MEASURES.*

Having given a summary description of the instruments belonging to the section of standards of length, we shall now speak of those that pertain to that of the standards of weight.

The essential instrument of this section is naturally the balance. The Bureau possesses one of the most remarkable collections of balances of precision that exist in the world. The chief of these were constructed by the house of Ruprecht, of Vienna, Austria. Our large engraving represents, as a whole, the beautiful and spacious hall in which these are mounted. We give, in addition (Fig. 1), an engraving of the balance that is specially designed for comparing standard kilogrammes. This balance is so arranged that it can be maneuvered from a distance, the injurious influence thus being avoided that the near-by presence of the observer always exerts upon weighings, through the disturbances of temperature that he produces near the instrument. Here the observer, who has previously made his preparations, that is to say, who has placed in the case of the instrument, at the necessary places, the weights that he will need, no longer approaches the balance. Standing in front of his spy-glass, he performs all the operations connected with weighing; that is, puts the weights on the pans, and unfastens the latter, then the beam, measures the latter's oscillations, then changes the weights, putting the one that was on the right to the left, and *vice versa*, and doing all this from a distance of four meters. For this purpose the balance is provided with a very ingenious and perfectly accurate mechanism, which is controlled by means of winches fixed at the extremity of long rods. The oscillations of the beam are read through the reflection of a divided scale from a mirror that is carried by the beam; and it is the image of this scale that the observer sees slowly move in his spy-glass while the balance is oscillating. He notes a certain number of successive *elongations*, and deduces from these by calculation the position of equilibrium.

Three other balances of the same model, but smaller, are designed for comparisons and adjustments of lighter weights. These possess the same transposing mechanism, which is a little simplified, however, and less complete in the two smallest ones. There will be seen in the center of Fig. 2 the long lever-arms that permit of weighing from a distance, and that are connected with three masonry pillars, over which are placed the spy-glasses for reading the oscillations of the beam.

* Continued from SCIENTIFIC AMERICAN No. 11, page 164.

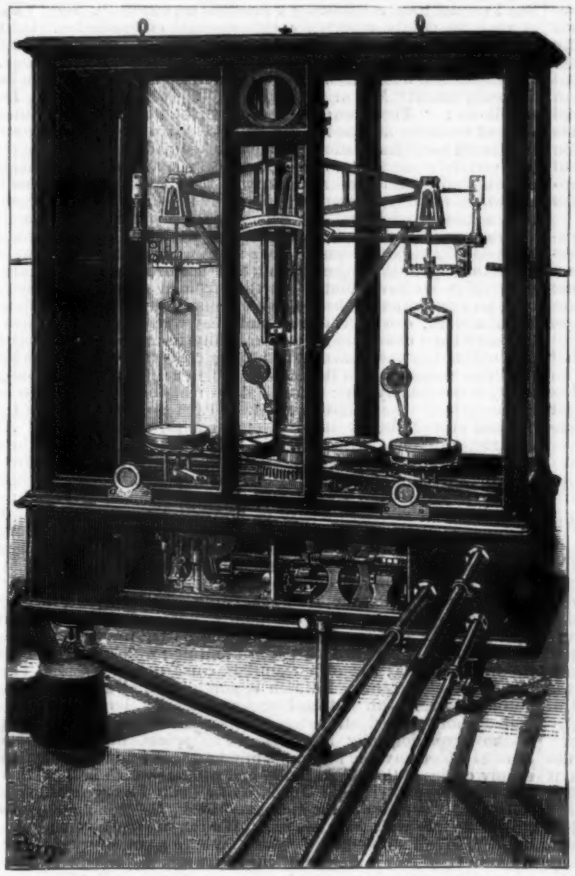


FIG. 1.—BALANCE FOR COMPARING STANDARD KILOGRAMME WEIGHTS.

The following are a few details in regard to the transposing mechanism of the balance: The scale-pans have a very peculiar form. Each of them consists of a ring which is open at one point, and which is prolonged inwardly by four triangles or teeth that point toward the center. Between these teeth passes a cross which is situated beneath. Let us suppose that a weight (1 kilogramme, for example) has been put on to each of the scale-pans; and, to fix our ideas, let us suppose that the kilogramme, A, is on the left pan and the kilogramme, B, is on the right one. The observer, seizing one of the four winches that are within reach, sets the mechanism in motion. Then the cross beneath the pan rises in the first place, moves beyond the plane of the pan, and lifts the kilogramme weight lying thereon, and then, having reached the proper height, moves laterally, and, disconnecting itself from the pan, places itself above one of the disks that are situated to the right and left at the base of the balance. These disks have an arrangement analogous to that of the scale-pans. Continuing its movement, the cross then begins to descend and traverse the plane of the disk, depositing thereon as it does so the kilogramme weight that it has removed from the pan. While these movements are occurring on the left with the weight, A, they are simultaneously taking place on the right with the weight, B. The two weights to be compared are thus carried at the same time to the central disks. Seizing, then, a second winch, the observer causes the two disks to revolve 180° around the axis of the instrument's standard, thus placing to the right that which was at the left and *vice versa*. It is now only necessary to make the cross perform the same evolution again, but in an opposite direction, to bring the weights again upon the scale-pans. The weight, A, will now be at the right, and B at the left, and the observer may effect the second phase of the operation. Of the two other winches, one controls the motion that serves to disengage the scale-pans, and the other the motion that depresses the fork and frees the beam.

As well known for a long time, the balance is *the* instrument of precision *par excellence*. With those under consideration, errors in weighing may be lessened to an almost indefinite degree. Thus, the difference between two kilogramme weights may be

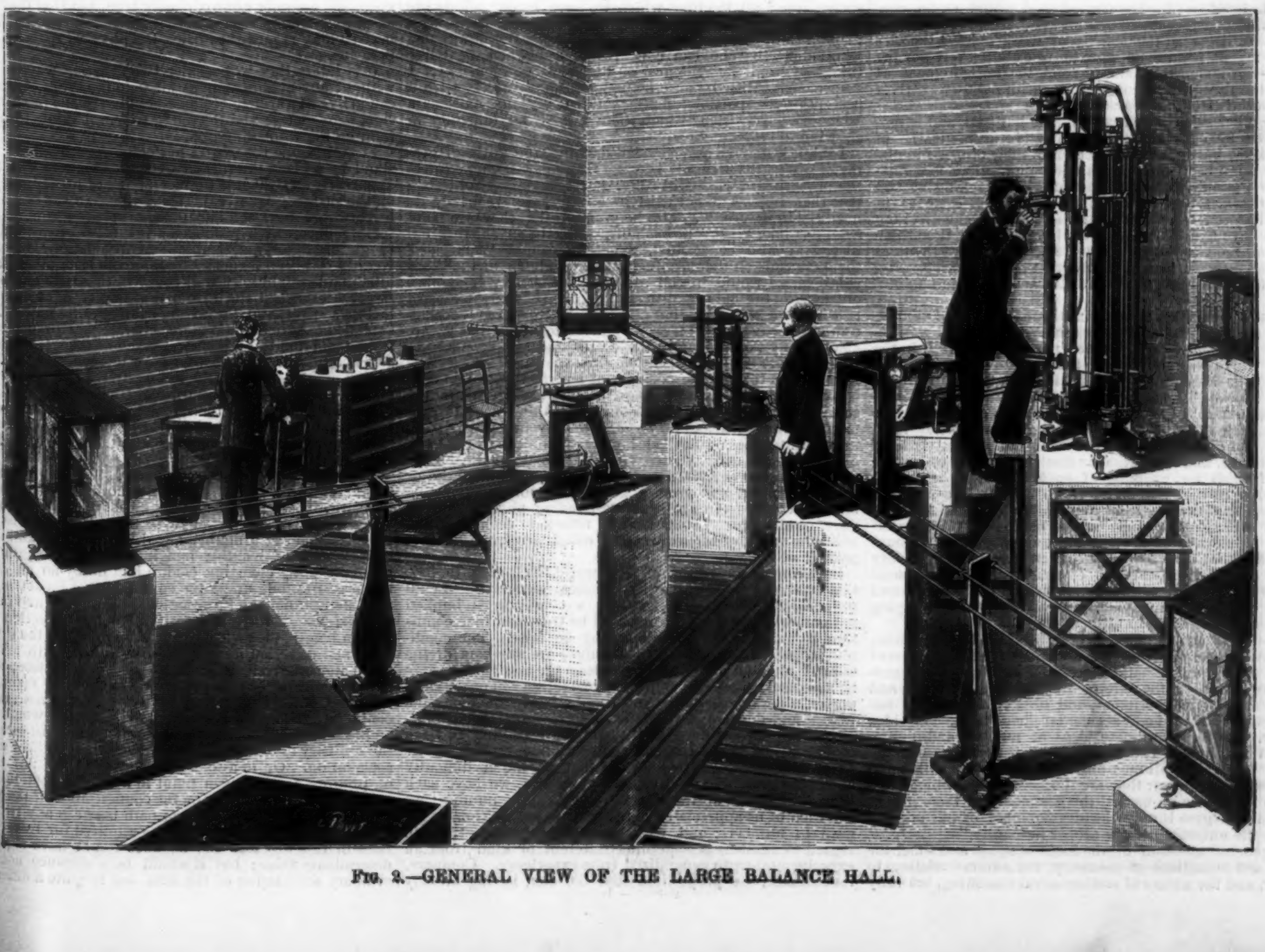


FIG. 2.—GENERAL VIEW OF THE LARGE BALANCE HALL.

estimated with an exactness of one one-hundredth of a millimeter; that is to say, a kilogramme weight may be weighed to within one hundred-thousandth of its value.

In another hall there is mounted a hydrostatic balance, which serves for determining densities. Here again all the details of the operations are of the most perfect character. The water which is to serve for hydrostatic weighing is first distilled in an ordinary retort, then redistilled by means of a platinum apparatus, and finally collected in a platinum vessel. This latter, which is placed under the balance, is employed for the weighings; and a series of ingenious apparatus permits of the weight being plunged into the water, and of the necessary manipulations being effected in such a way as to reduce to a minimum every chance of error that could intervene.

The section of weights possesses, in addition, a fine collection of iridized platinum and quartz weights for comparing weights of the first class, and of gilded brass ones for those of the second class.

Besides the fundamental apparatus just mentioned, the Bureau is provided with a large number of different instruments, some designed for certain special work, and others that are necessary for those special studies that are forcedly connected with the operations of comparing or weighing. Among the first, one of the most remarkable for the great delicacy of the method that it brings in play is the Fizeau apparatus, by means of which expansions are measured upon small specimens or fragments of a few millimeters thickness only, by the use of an optical process founded on the observation of a phenomenon of the interference of light. This apparatus permits of ascertaining and measuring variations in diameter between two points of a *few thousandths* of a millimeter.

The accessory instruments are cathetometers, spherometers, etc., as well as barometers, thermometers, and hygrometers. Fig. 2 shows, for example, the normal barometer of the section of weights, a large instrument in which are combined every improvement that could permit of measuring the pressure of the atmosphere with the highest degree of accuracy possible.

The ascertaining of the temperature plays an essential part in all the operations that have to be performed on standards, either of length or of weight. So the studies that relate to thermometry hold so important a position that it might be considered as constituting a section apart, comprising its special instruments also.—*La Nature.*

MATHEMATICS.

BRITISH ASSOCIATION, SOUTHPORT, 1883. INAUGURAL ADDRESS BY ARTHUR CAYLEY, M.A., D.C.L., LL.D., F.R.S., SADLERIAN PROFESSOR OF PURE MATHEMATICS IN THE UNIVERSITY OF CAMBRIDGE, PRESIDENT.

MATHEMATICS connect themselves on the one side with common life and the physical sciences; on the other side with philosophy, in regard to our notions of space and time; and in the questions which have arisen as to the universality and necessity of the truths of mathematics, and the foundation of our knowledge of them. I would remark here that the connection (if it exists) of arithmetic and algebra with the notion of time is far less obvious than that of geometry with the notion of space.

As to the former side, I am not making before you a defense of mathematics, but if I were I should desire to do it—in such manner as in the "Republic" Socrates was required to defend justice, quite irrespectively of the worldly advantages which may accompany a life of virtue and justice, and to show that, independently of all these, justice was a thing desirable in itself and for its own sake—*not* by speaking to you of the utility of mathematics in any of the questions of common life or of physical science. Still less would I speak of this utility before, I trust, a friendly audience interested or willing to appreciate an interest in mathematics in itself and for its own sake. I would, on the contrary, rather consider the obligations of mathematics to these different subjects as the sources of mathematical theories now as remote from them, and in as different a region of thought—for instance, geometry from the measurement of land, or the theory of numbers from arithmetic—as a river at its mouth is from its mountain source.

On the other side the general opinion has been and is that it is indeed by experience that we arrive at the truths of mathematics, but that experience is not their proper foundation; the mind itself contributes something. This is involved in the Platonic theory of reminiscence; looking at two things, trees or stones or anything else, which seem to us more or less equal, we arrive at the idea of equality: but we must have had this idea of equality before the time when first seeing the two things we were led to regard them as coming up more or less perfectly to this idea of equality; and the like as regards our idea of the beautiful, and in other cases.

The same view is expressed in the answer of Leibnitz, the *nisi intellectus ipse*, to the scholastic dictum, *nihil in intellectu quod non prius in sensu*: there is nothing in the intellect which was not first in the sensation, except (said Leibnitz) the intellect itself. And so again in the "Critick of Pure Reason," Kant's view is that, while there is no doubt but that all our cognition begins with experience, we are nevertheless in possession of cognitions *a priori*, independent, not of this or that experience, but absolutely so of all experience, and in particular that the axioms of mathematics furnish an example of such cognitions *a priori*. Kant holds further that space is no empirical conception which has been derived from external experiences, but that in order that sensations may be referred to something external, the representation of space must already lie at the foundation; and that the external experience is itself first only possible by this representation of space. And in like manner time is no empirical conception which can be deduced from an experience, but it is a necessary representation lying at the foundation of all intuitions.

And so in regard to mathematics, Sir W. R. Hamilton, in an introductory lecture on astronomy (1836), observes: "These purely mathematical sciences of algebra and geometry are sciences of the pure reason, deriving no weight and no assistance from experiment, and isolated or at least isolable from all outward and accidental phenomena. The idea of order, with its subordinate ideas of number and figure, we must not indeed call innate ideas, if that phrase be defined to imply that all men must possess them with equal clearness and fullness: they are, however, ideas which seem to be so far born with us that the possession of them in any conceivable degree is only the development of our original powers, the unfolding of our proper humanity."

The general question of the ideas of space and time, the axioms and definitions of geometry, the axioms relating to number, and the nature of mathematical reasoning, are fully and ably discussed in Whewell's "Philosophy of the Inductive Sciences" (1840), which may be regarded as containing an exposition of the whole theory.

But it is maintained by John Stuart Mill that the truths of mathematics, in particular those of geometry, rest on experience; and, as regards geometry, the same view is on very different grounds maintained by the mathematician Riemann.

It is not so easy as at first sight it appears to make out how far the views taken by Mill in his "System of Logic, Ratiocinative and Inductive" (ninth edition, 1879) are absolutely contradictory to those which have been spoken of; they profess to be so; there are most definite assertions (supported by argument), for instance, p. 263: "It remains to inquire what is the ground of our belief in axioms, what is the evidence on which they rest. I answer, they are experimental truths, generalizations from experience. The proposition, 'Two straight lines cannot inclose a space,' or, in other words, two straight lines which have once met cannot meet again, is an induction from the evidence of our senses." But I cannot help considering a previous argument (p. 259) as very materially modifying this absolute contradiction. After inquiring, "Why are mathematics by almost all philosophers . . . considered to be independent of the evidence of experience and observation, and characterized as systems of necessary truth?" Mill proceeds (I quote the whole passage) as follows: "The answer I conceive to be that this character of necessity ascribed to the truths of mathematics, and even (with some reservations to be hereafter made) the peculiar certainty ascribed to them, is a delusion, in order to sustain which it is necessary to suppose that those truths relate to and express the properties of purely imaginary objects. It is acknowledged that the conclusions of geometry are derived partly at least from the so-called definitions, and these definitions are assumed to be correct representations, so far as they go, of the objects with which geometry is conversant. Now we have pointed out that from a definition as such no proposition, unless it be one concerning the meaning of a word, can ever follow, and that what apparently follows from a definition follows in reality from an implied assumption that there exists a real thing conformable thereto. This assumption in the case of the definitions of geometry is not strictly true; there exist no real things exactly conformable to the definitions. There exist no real points without magnitude, no lines without breadth, nor perfectly straight, no circles with all their radii exactly equal, nor squares with all their angles perfectly right. It will be said that the assumption does not extend to the actual, but only to the possible existence of such things. I answer that according to every test we have of possibility they are not even possible. Their existence, so far as we can form any judgment, would seem to be inconsistent with the physical constitution of our planet at least, if not of the universal [*sic*]. To get rid of this difficulty, and at the same time to save the credit of the supposed system of necessary truths, it is customary to say that the points, lines, circles, and squares which are the subjects of geometry exist in our conceptions merely, and are parts of our minds; which minds, by working on their own materials, construct an *a priori* science, the evidence of which is purely mental and has nothing to do with outward experience. By howsoever high authority this doctrine has been sanctioned, it appears to me psychologically incorrect. The points, lines, and squares which any one has in his mind are (as I apprehend) simply copies of the points, lines, and squares which he has known in his experience. Our idea of a point I apprehend to be simply our idea of the *minimum visible*, the small portion of surface which we can see. We can reason about a line as if it had no breadth, because we have a power which we can exercise over the operations of our minds; the power, when a perception is present to our senses or a conception to our intellects, of *attending* to a part only of that perception or conception instead of the whole. But we cannot *conceive* a line without a breadth; we can form no mental picture of such a line: all the lines which we have in our minds are lines possessing breadth. If any one doubt this, we may refer him to his own experience. I much question if any one who fancies that he can conceive of a mathematical line thinks so from the evidence of his own consciousness. I suspect it is rather because he supposes that unless such a perception be possible, mathematics could not exist as a science: a supposition which there will be no difficulty in showing to be groundless."

I think it may be at once conceded that the truths of geometry are truths precisely because they relate to and express the properties of what Mill calls "purely imaginary objects"; that these objects do not exist in Mill's sense, that they do not exist in nature, may also be granted; that they are "not even possible," if this means not possible in an existing nature, may also be granted. That we cannot "conceive" them depends on the meaning which we attach to the word conceive. I would myself say that the purely imaginary objects are the only realities, the ὄντως ὄντα, in regard to which the corresponding physical objects are as the shadows in the cave; and it is only by means of them that we are able to deny the existence of a corresponding physical object; if there is no conception of straightness, then it is meaningless to deny the existence of a perfectly straight line.

But at any rate the objects of geometrical truth are the so-called imaginary objects of Mill, and the truths of geometry are only true, and *a fortiori* are only necessarily true, in regard to these so-called imaginary objects; and these objects, points, lines, circles, etc., in the mathematical sense of the terms, have a likeness to and are represented more or less imperfectly, and from a geometer's point of view no matter how imperfectly, by corresponding physical points, lines, circles, etc. I shall have to return to geometry, and will then speak of Riemann, but I will first refer to another passage of the "Logic."

Speaking of the truths of arithmetic, Mill says (p. 297) that even here there is one hypothetical element: "In all propositions concerning numbers a condition is implied without which none of them would be true, and that condition is an assumption which may be false. The condition is that $1 = 1$; that all the numbers are numbers of the same or of equal units." Here at least the assumption may be absolutely true; one shilling = one shilling in purchasing power, although they may not be absolutely of the same weight and fineness; but it is hardly necessary; one coin + one coin = two coins, even if the one be a shilling and the other a half crown. In fact, whatever difficulty be raisable as to geometry, it seems to me that no similar difficulty applies to arithmetic; mathematician or not, we have each of us, in its most abstract form, the idea of a number; we can each of us appreciate the truth of a proposition in regard to numbers; and we cannot but see that a truth in regard to numbers is something different in kind from an experimental truth generalized from experience. Compare, for instance, the proposition that the sun, having already risen so many times, will rise to-morrow, and the next day, and the day after that, and so on; and the proposition that even and odd numbers succeed each other alternately *ad infinitum*: the latter at least seems to have the characters of universality and necessity. Or, again, suppose a proposition observed to hold good for a long series of numbers, one thousand numbers, two thousand numbers, as the case may be: this is not only no proof, but it is absolutely no evidence, that the proposition is a true proposition, holding good for all numbers whatever; there are in the theory of numbers very remarkable instances of propositions observed to hold good for very long series of numbers, and which are nevertheless untrue.

I pass in review certain mathematical theories.

In arithmetic and algebra, or say in analysis, the numbers or magnitudes which we represent by symbols are in the first instance ordinary (that is, positive) numbers or magnitudes. We have also in analysis and in analytical geometry *negative* magnitudes; there has been in regard to these plenty of philosophical discussion, and I might refer to Kant's paper, "Ueber die negativen Grossen in die Weltweisheit" (1763), but the notion of a negative magnitude has become quite a familiar one, and has extended itself into common phraseology. I may remark that it is used in a very refined manner in bookkeeping by double entry.

But it is far otherwise with the notion which is really the fundamental one (and I cannot too strongly emphasize the assertion) underlying and pervading the whole of modern analysis and geometry, that of imaginary magnitude in analysis and of imaginary space (or space as a *locus in quo* of imaginary points and figures) in geometry. I use in each case the word imaginary as including real. This has not been, so far as I am aware, a subject of philosophical discussion or inquiry. As regards the older metaphysical writers, this would be quite accounted for by saying that they knew nothing, and were not bound to know anything about it; but at present, and considering the prominent position which the notion occupies—say even that the conclusion were that the notion belongs to mere technical mathematics, or has reference to nonentities in regard to which no science is possible, still it seems to me that (as a subject of philosophical discussion), the notion ought not to be thus ignored; it should at least be shown that there is a right to ignore it.

Although in logical order I should perhaps now speak of the notion just referred to, it will be convenient to speak first of some other quasi-geometrical notions; those of more than three dimensional space, and of non-Euclidian two and three dimensional space, and also of the generalized notion of distance. It is in connection with these that Riemann considered that our notion of space is founded on experience, or rather that it is only by experience that we know that our space is Euclidian space.

It is well known that Euclid's twelfth axiom, even in Playfair's form of it, has been considered as needing demonstration, and that Lobatschewsky constructed a perfectly consistent theory wherein this axiom was assumed not to hold good, or say a system of non-Euclidian plane geometry. There is a like system of non-Euclidian solid geometry. My own view is that Euclid's twelfth axiom in Playfair's form of it does not need demonstration, but is part of our notion of space, of the physical space of our experience—the space, that is, which we become acquainted with by experience, but which is the representation lying at the foundation of all external experience. Riemann's view before referred to may I think be said to be that, having *in intellectu* a more general notion of space (in fact, a notion of non-Euclidian space), we learn by experience that space (the physical space of our experience) is, if not exactly, at least to the highest degree of approximation, Euclidian space.

But, suppose the physical space of our experience to be thus only approximately Euclidian space, what is the consequence which follows? *Not* that the propositions of geometry are only approximately true, but that they remain absolutely true in regard to that Euclidian space which has been so long regarded as being the physical space of our experience.

It is interesting to consider two different ways in which, without any modification at all of our notion of space, we can arrive at a system of non-Euclidian (plane or two-dimensional) geometry; and the doing so will, I think, throw some light on the whole question.

First, imagine the earth a perfectly smooth sphere; understand by a plane the surface of the earth, and by a line the apparently straight line (in fact, an arc of great circle) drawn on the surface; what experience would in the first instance teach would be Euclidian geometry; there would be intersecting lines which produced a few miles or so would seem to go on diverging, and apparently parallel lines which would exhibit no tendency to approach each other; and the inhabitants might very well conceive that they had by experience established the axiom that two straight lines cannot inclose a space, and the axiom as to parallel lines. A more extended experience and more accurate measurements would teach them that the axioms were each of them false; and that any two lines if produced far enough each way would meet in two points; they would in fact arrive at a spherical geometry, accurately representing the properties of the two-dimensional space of their experience. But their original Euclidian geometry would not the less be a true system; only it would apply to an ideal space, not the space of their experience.

Secondly, consider an ordinary, indefinitely extended plane; and let us modify only the notion of distance. We measure distance, say, by a yard measure or a foot rule, anything which is short enough to make the fractions of it of no consequence (in mathematical language by an infinitesimal element of length); imagine, then, the length of this rule constantly changing (as it might do by an alteration of temperature), but under the condition that its actual length shall depend only on its situation on the plane and on its direction; viz., if for a given situation and direction it has a certain length, then whenever it comes back to the same situation and direction it must have the same length. The distance along a given straight or curved line between any two points could then be measured in the ordinary manner with this rule, and would have a perfectly determinate value; it could be measured over and over again, and would always be the same: but, of course, it would be the distance not in the ordinary acceptation of the term, but in quite a different acceptation. Or in a somewhat different way: if the rate of progress from a given point in a given direction be conceived as depending only on the configuration of the ground, and the distance along a given path between any two points thereof be measured by the time required for traversing it, then in this way also the distance would have a perfectly determinate value; but it would be a distance not in the ordinary acceptation of the term but in quite a different ac-

ceptation. And corresponding to the new notion of distance, we should have a new, non-Euclidian system of plane geometry; all theorems involving the notion of distance would be altered.

We may proceed further. Suppose that as the rule moves away from a fixed central point of the plane it becomes shorter and shorter; if this shortening takes place with sufficient rapidity, it may very well be that a distance which in the ordinary sense of the word is finite will in the new sense be infinite; no number of repetitions of the length of the ever shortening rule will be sufficient to cover it. There will be surrounding the central point of a certain finite area such that (in the new acceptation of the term distance) each point of the boundary thereof will be at an infinite distance from the central point; the points outside this area you cannot by any means arrive at with your rule; they will form a *terra incognita*, or rather an unknowable land: in mathematical language, an imaginary or impossible space: and the plane space of the theory will be that within the finite area—that is, it will be finite instead of infinite.

We thus with a proper law of shortening arrive at a system of non-Euclidian geometry which is essentially that of Lobatschewsky. But in so obtaining it we put out of sight its relation to spherical geometry: the three geometries (spherical, Euclidian, and Lobatschewsky's) should be regarded as members of a system, viz., they are the geometries of a plane (two-dimensional) space of constant positive curvature, zero-curvature, and constant negative curvature respectively; or, again, they are the plane geometries corresponding to three different notions of distance; in this point of view they are Klein's elliptic, parabolic, and hyperbolic geometries respectively.

Next, as regards solid geometry: we can by a modification of the notion of distance (such as has just been explained in regard to Lobatschewsky's system) pass from our present system to a non-Euclidian system; for the other mode of passing to a non-Euclidian system it would be necessary to regard our space as a flat three-dimensional space existing in a space of four dimensions (*i. e.*, as the analogue of a plane existing in ordinary space); and to substitute for such flat three-dimensional space a curved three-dimensional space, say of constant positive or negative curvature. In regarding the physical space of our experience as possibly non-Euclidian, Riemann's idea seems to be that of modifying the notion of distance, not that of treating it as a locus in four-dimensional space,

I have just come to speak of four-dimensional space. What meaning do we attach to it? or can we attach to it any meaning? It may be at once admitted that we cannot conceive of a fourth dimension of space: that space as we conceive of it, and the physical space of our experience, are alike three-dimensional; but we can, I think, conceive of space as being two or even one dimensional; we can imagine rational beings living in a one-dimensional space (a line) or in a two-dimensional space (a surface), and conceiving of space accordingly, and to whom, therefore, a two-dimensional space, or (as the case may be) a three dimensional space, would be as inconceivable as a four-dimensional space is to us. And very curious speculative questions arise. Suppose the one-dimensional space a right line, and that it afterward becomes a curved line; would there be any indication of the change? Or, if originally a curved line, would there be anything to suggest to them that it was not a right line? Probably not, for a one-dimensional geometry hardly exists. But let the space be two-dimensional, and imagine it originally a plane, and afterward bent (converted, that is, into some form of developable surface) or converted into a curved surface; or imagine it originally a developable or curved surface. In the former case there should be an indication of the change, for the geometry originally applicable to the space of their experience (our own Euclidian geometry) would cease to be applicable; but the change could not be apprehended by them as a bending or deformation of the plane, for this would imply the notion of a three-dimensional space in which this bending or deformation could take place. In the latter case their geometry would be that appropriate to the developable or curved surface which is their space: viz., this would be their Euclidian geometry; would they ever have arrived at our own more simple system? But take the case where the two-dimensional space is a plane, and imagine the beings of such a space familiar with our own Euclidian plane geometry; if, a third dimension being still inconceivable by them, they were by their geometry or otherwise led to the notion of it, there would be nothing to prevent them from forming a science such as our own science of three-dimensional geometry.

Evidently all the foregoing questions present themselves in regard to ourselves, and to three-dimensional space as we conceive of it, and as the physical space of our experience. And I need hardly say that the first step is the difficulty, and that granting a fourth dimension we may assume as many more dimensions as we please. But whatever answer be given to them, we have, as a branch of mathematics, potentially if not actually, an analytical geometry of n-dimensional space. I shall have to speak again upon this.

Coming now to the fundamental notion already referred to, that of imaginary magnitude in analysis and imaginary space in geometry: I connect this with two great discoveries in mathematics made in the first half of the seventeenth century—Harriot's representation of an equation in the form $f(x) = 0$, and the consequent notion of the roots of an equation as derived from the linear factors of $f(x)$ (Harriot, 1560–1621: his "Algebra," published after his death, has the date 1631), and Descartes' method of co-ordinates, as given in the "Geometrie," forming a short supplement to his "Traité de la Méthode, etc." (Leyden, 1637).

I show how by these we are led analytically to the notion of imaginary points in geometry; for instance, we arrive at the theorem that a straight line and circle in the same plane intersect *always* in two points, real or imaginary. The conclusion as to the two points of intersection cannot be contradicted by experience: take a sheet of paper and draw on it the straight line and circle, and try. But you might say, or at least be strongly tempted to say, that it is meaningless. The question of course arises, What is the meaning of an imaginary point? and, further, In what manner can the notion be arrived at geometrically?

There is a well known construction in perspective for drawing lines through the intersection of two lines which are so nearly parallel as not to meet within the limits of the sheet of paper. You have two given lines which do not meet, and you draw a third line, which, when the lines are all of them produced, is found to pass through the intersection of the given lines. If instead of lines we have two circular arcs not meeting each other, then we can, by means of these arcs, construct a line; and if on completing the circles it is found that the circles intersect each other in two real points, then it will be found that the line passes through these two points. If the circles appear not to intersect, then the line will appear not to intersect either of the circles. But the geometrical construction being in each case the same, we say that in the second case also the line passes through the two intersections of the circles.

Of course it may be said in reply that the conclusion is a very natural one, provided we assume the existence of imaginary points; and that, this assumption not being made, then, if the circles do not intersect, it is meaningless to assert that the line passes through their points of intersection. The difficulty is not got over by the analytical method before referred to, for this introduces difficulties of its own. Is there in a plane a point, the co-ordinates of which have given imaginary values? As a matter of fact, we do consider in plane geometry imaginary points introduced into the theory analytically or geometrically as above.

The like considerations apply to solid geometry, and we thus arrive at the notion of imaginary space as a *locus in quo* of imaginary points and figures.

I have used the word imaginary rather than complex, and I repeat that the word has been used as including real. But, this once understood, the word becomes in many cases superfluous, and the use of it would even be misleading. Thus, "a problem has so many solutions;" this means so many imaginary (including real) solutions. But if it were said that the problem had "so many imaginary solutions," the word "imaginary" would here be understood to be used in opposition to real. I give this explanation the better to point out now wide the application of the notion of the imaginary is, viz. (unless expressly or by implication excluded), it is a notion implied and presupposed in all the conclusions of modern analysis and geometry. It is, as I have said, the fundamental notion underlying and pervading the whole of these branches of mathematical science.

I consider the question of the geometrical representation of an imaginary variable. We represent the imaginary variable $x + iy$ by means of a point in a plane, the co-ordinates of which are x, y. This idea, due to Gauss, dates from about the year 1831. We thus picture to ourselves the succession of values of the imaginary variable $x + iy$ by means of the motion of the representative point: for instance, the succession of values corresponding to the motion of the point along a closed curve to its original position. The value $X + iY$ of the function can, of course, be represented by means of a point (taken for greater convenience in a different plane), the co-ordinates of which are X, Y.

We may consider in general two points, moving each in its own plane, so that the position of one of them determines the position of the other, and consequently the motion of the one determines the motion of the other; for instance, the two points may be the tracing point and the pencil of a pantograph. You may with the first point draw any figure you please, there will be a corresponding figure drawn by the second point. For a good pantograph a copy on a different scale (it may be); for a badly adjusted pantograph, a distorted copy; but the one figure will always be a sort of copy of the first, so that to each point of the one figure there will correspond a point in the other figure.

In the case above referred to, where one point represents the value $x + iy$ of the imaginary variable and the other the value $X + iY$ of some function $\varphi(x + iy)$ of that variable, there is a remarkable relation between the two figures: this is the relation of orthomorphic projection, the same which presents itself between a portion of the earth's surface and the representation thereof by a map on the stereographic projection or on Mercator's projection—viz., any indefinitely small area of the one figure is represented in the other figure by an indefinitely small area of the same shape. There will possibly be for different parts of the figure great variations of scale, but the shape will be unaltered; if for the one area the boundary is a circle, then for the other area the boundary will be a circle; if for one it is an equilateral triangle, then for the other it will be an equilateral triangle.

I have been speaking of an imaginary variable $(x + iy)$, and of a function $\varphi(x + iy) = X + iY$ of that variable, but the theory may equally well be stated in regard to a plane curve; in fact, the $x + iy$ and the $X + iY$ are two imaginary variables connected by an equation; say their values are u and v, connected by an equation $F(u, v) = 0$; then, regarding u, v as the co-ordinates of a point *in plano*, this will be a point on the curve represented by the equation. The curve, in the widest sense of the expression, is the whole series of points, real or imaginary, the co-ordinates of which satisfy the equation, and these are exhibited by the foregoing corresponding figures in two planes; but in the ordinary sense the curve is the series of real points, with co-ordinates u, v, which satisfy the equation.

In geometry, it is the curve, whether defined by means of its equation, or in any other manner, which is the subject for contemplation and study. But we also use the curve as a representation of its equation—that is, of the relation existing between two magnitudes, x, y, which are taken as the co-ordinates of a point on the curve. Such employment of a curve for all sorts of purposes—the fluctuations of the barometer, the Cambridge boat races, or the Funds—is familiar to most of you. It is in like manner convenient in analysis, for exhibiting the relations between any three magnitudes, x, y, z, to regard them as the co-ordinates of a point in space; and, on the like ground, we should at least wish to regard any four or more magnitudes as the co-ordinates of a point in space of a corresponding number of dimensions. Starting with the hypothesis of such a space, and of points therein, each determined by means of its co-ordinates, it is found possible to establish a system of n-dimensional geometry analogous in every respect to our two and three-dimensional geometries, and to a very considerable extent serving to exhibit the relations of the variables.

It is to be borne in mind that the space, whatever its dimensionality may be, must always be regarded as an imaginary or complex space, such as the two or three-dimensional space of ordinary geometry; the advantages of the representation would otherwise altogether fail to be obtained.

I omit some further developments in regard to geometry; and all that I have written as to the connection of mathematics with the notion of time.

I said that I would speak to you, not of the utility of the mathematics in any of the questions of common life or of physical science, but rather of the obligations of mathematics to these different subjects. The consideration which thus presents itself is in a great measure that of the history of the development of the different branches of mathematical science in connection with the older physical sciences, astronomy and mechanics; the mathematical theory is in the first instance suggested by some question of common life or of physical science, is pursued and studied quite independently thereof, and perhaps after a long interval comes in contact with it, or with quite a different question. Geometry and algebra must, I think, be considered as each of them originating in connection with objects or questions of common life—geometry, notwithstanding its name, hardly in the measurement of land, but rather from the contemplation of such forms as the straight line, the circle, the ball, the top (or sugar-loaf); the Greek geometers appropriated for the geometrical forms corresponding to the last two of these, the words σφαῖρα and κῶνος, our cone and sphere, and they extended the word cone to mean the complete figure obtained by producing the straight lines of the surface both ways indefinitely. And so algebra would seem to have arisen from the sort of easy puzzles in regard to numbers which may be made, either in the picturesque forms of the Bija-Ganita with its maiden with the beautiful locks, and its swarms of bees amid the fragrant blossoms, and the one queen bee left humming around the lotus flower; or in the more prosaic form in which a student has presented to him in a modern text-book a problem leading to a simple equation.

The Greek geometry may be regarded as beginning with Plato (B.C. 430–347): the notions of geometrical analysis, loci, and the conic sections are attibuted to him, and there are in his "Dialogues" many very interesting allusions to mathematical questions; in particular the passage in the "Theætetus," where he affirms the incommensurability of the sides of certain squares. But the earliest extant writings are those of Euclid (B.C. 285); there is hardly anything in mathematics more beautiful than his wondrous fifth book; and he has also in the seventh, eighth, ninth, and tenth books fully and ably developed the first principles of the theory of numbers, including the theory of incommensurables. We have next Apollonius (about B.C. 247) and Archimedes (B.C. 287–212), both geometers of the highest merit, and the latter of them the founder of the science of statics (including therein hydrostatics): his dictum about the lever, his "Εὔρηκα," and the story of the defense of Syracuse are well known. Following these we have a worthy series of names, including the astronomers Hipparchus (B.C. 150) and Ptolemy (A.D. 125), and ending, say, with Pappus (A.D. 400), but continued by their Arabian commentator, and the Italian and other European geometers of the sixteenth century and later, who pursued the Greek geometry.

The Greek arithmetic was, from the want of a proper notation, singularly cumbrous and difficult; and it was for astronomical purposes superseded by the sexagesimal arithmetic, attributed to Ptolemy, but probably known before his time. The use of the present so-called Arabic figures became general among Arabian writers on arithmetic and astronomy about the middle of the tenth century, but it was not introduced into Europe until about two centuries later. Algebra among the Greeks is represented almost exclusively by the treatise of Diophantus (A.D. 150), in fact a work on the theory of numbers containing questions relating to square and cube numbers, and other properties of numbers, with their solutions; this has no historical connection with the later algebra introduced into Italy from the East by Leonardi Bonacci of Pisa (A.D. 1202–1208), and successfully cultivated in the fifteenth and sixteenth centuries by Lucas Paciolus or De Burgo, Tartaglia, Cardan, and Ferrari. Later on we have Vieta (1540–1603), Harriot, already referred to, Wallis, and others.

Astronomy is of course intimately connected with geometry; the most simple facts of observation of the heavenly bodies can only be *stated* in geometrical language; for instance, that the stars describe circles about the Pole star, or that the different positions of the sun among the fixed stars in the course of the year form a circle. For astronomical calculations it was found necessary to determine the arc of a circle by means of its chord; the notion is as old as Hipparchus, a work of whom is referred to as consisting of twelve books on the chords of circular arcs; we have (A.D. 125) Ptolemy's "Almagest," the first book of which contains a table of arcs and chords with the method of construction; and among other theorems on the subject he gives there the theorem afterward inserted in Euclid (Book VI., Prop. D) relating to the rectangle contained by the diagonals of a quadrilateral inscribed in a circle. The Arabians made the improvement of using in place of the chord of an arc the sine, or half chord of double the arc, and so brought the theory into the form in which it is used in modern trigonometry: the before-mentioned theorem of Ptolemy, or rather a particular case of it, translated into the notation of sines, gives the expression for the sine of the sum of two arcs in terms of the sines and cosines of the component arcs; and it is thus the fundamental theorem on the subject. We have in the fifteenth and sixteenth centuries a series of mathematicians who with wonderful enthusiasm and perseverance calculated tables of the trigonometrical or circular functions, Purbach, Müller or Regiomontanus, Copernicus, Reinhold, Maurolycus, Vieta, and many others; the tabulations of the functions tangent and secant are due to Reinhold and Maurolycus respectively.

Logarithms were invented, not exclusively with reference to the calculation of trigonometrical tables, but in order to facilitate numerical calculations generally; the invention is due to John Napier of Merchiston, who died in 1618 at sixty-seven years of age; the notion was based upon refined mathematical reasoning on the comparison of the spaces described by two points, the one moving with a uniform velocity, the other with a velocity varying according to a given law. It is to be observed that Napier's logarithms were nearly but not exactly those which are now called (sometimes Napierian, but more usually) hyperbolic logarithms—those to the base e; and that the change to the base 10 (the great step by which the invention was perfected for the object in view) was indicated by Napier but actually made by Henry Briggs, afterward Savilian Professor at Oxford (d. 1630). But it is the hyperbolic logarithm which is mathematically important. The direct function e^x or exp. x, which has for its inverse the hyperbolic logarithm, presented itself, but not in a prominent way. Tables were calculated of the logarithms of numbers, and of those of the trigonometrical functions.

The circular function and the logarithm were thus invented each for a practical purpose, separately and without any proper connection with each other. The functions are connected through the theory of imaginaries, and form together a group of the utmost importance throughout mathematics: but this is mathematical theory; the obligation of mathematics is for the discovery of the functions.

Forms of spirals presented themselves in Greek architecture, and the curves were considered mathematically by Archimedes; the Greek geometers invented some other curves, more or less interesting, but recondite enough in their origin. A curve which might have presented itself to anybody, that described by a point in the circumference of a rolling carriage wheel, was first noticed by Mersenne in 1615, and is the curve afterward considered by Roberval, Pascal, and others, under the name of the Roulette, other-

wise the Cycloid. Pascal (1623–1662) wrote at the age of seventeen his "Essais pour les Coniques," in seven short pages, full of new views on these curves, and in which he gives, in a paragraph of eight lines, his theory of the inscribed hexagon.

Kepler (1571–1630), by his empirical determination of the laws of planetary motion, brought into connection with astronomy one of the forms of conic, the eclipse, and established a foundation for the theory of gravitation. Contemporary with him, for most of his life, we have Galileo (1564–1642), the founder of the science of dynamics; and closely following upon Galileo, we have Isaac Newton (1643–1727): the "Philosophiæ naturalis Principia Mathematica," known as the "Principia," was first published in 1687.

The physical, statical, or dynamical questions which presented themselves before the publication of the "Principia" were of no particular mathematical difficulty, but it is quite otherwise with the crowd of interesting questions arising out of the theory of gravitation, and which, in becoming the subject of mathematical investigation, have contributed very much to the advance of mathematics. We have the problem of two bodies, or what is the same thing, that of the motion of a particle about a fixed center of force, for any law of force; we have also the (mathematically very interesting) problem of the motion of a body attracted to two or more fixed centers of force; and, next preceding that of the actual solar system, the problem of three bodies; this has ever been and is far beyond the power of mathematics, and it is in the lunar and planetary theories replaced by what is mathematically a different problem, that of the motion of a body under the action of a principal central force and a disturbing force; or (in one mode of treatment) by the problem of disturbed elliptic motion. I would remark that we have here an instance in which an astronomical fact, the observed slow variation of the orbit of a planet, has directly suggested a mathematical method, applied to other dynamical problems, and which is the basis of very extensive modern investigations in regard to systems of differential equations. Again, immediately arising out of the theory of gravitation, we have the problem of finding the attraction of a solid body of any given form upon a particle, solved by Newton in the case of a homogeneous sphere, but which is far more difficult in the next succeeding cases of the spheroid of revolution (very ably treated by Maclaurin) and of the ellipsoid of three unequal axes: there is perhaps no problem of mathematics which has been treated by as great a variety of methods, or has given rise to so much interesting investigation, as this last problem of the attraction of an ellipsoid upon an interior or exterior point. It was a dynamical problem, that of vibrating strings, by which Lagrange was led to the theory of the representation of a function as the sum of a series of multiple sines and cosines; and connected with this we have the expansions in terms of Legendre's functions P_n, suggested to him by the question just referred to of the attraction of an ellipsoid; the subsequent investigations of Laplace on the attractions of bodies differing slightly from the sphere led to the functions of two variables called Laplace's functions. I have been speaking of ellipsoids, but the general theory is that of attractions, which has become a very wide branch of modern mathematics. Associated with it we have in particular the names of Gauss, Lejeune-Dirichlet, and Green; and I must not omit to mention that the theory is now one relating to n-dimensional space. Another great problem of celestial mechanics, that of the motion of the earth about its center of gravity, in the most simple case, that of a body not acted upon by any forces, is a very interesting one in the mathematical point of view.

I may mention a few other instances where a practical or physical question has connected itself with the development of mathematical theory. I have spoken of two map projections—the stereographic, dating from Ptolemy; and Mercator's projection, invented by Edward Wright about the year 1600; each of these, as a particular case of the orthomorphic projection, belongs to the theory of the geometrical representation of an imaginary variable. I have spoken also of perspective, and (in an omitted paragraph) of the representation of solid figures employed in Monge's descriptive geometry. Monge, it is well known, is the author of the geometrical theory of the curvature of surfaces and of curves of curvature: he was led to this theory by a problem of earthwork—from a given area, covered with earth of uniform thickness, to carry the earth and distribute it over an equal given area, with the least amount of cartage. For the solution of the corresponding problem in solid geometry he had to consider the intersecting normals of a surface, and so arrived at the curves of curvature (see his "Memoire sur les Deblais et les Remblais," *Mem de l'Acad.*, 1781). The normals of a surface are, again, a particular case of a doubly infinite system of lines, and are so connected with the modern theories of congruences and complexes.

The undulatory theory of light led to Fresnel's wave surface, a surface of the fourth order, by far the most interesting one which had then presented itself. A geometrical property of this surface, that of having tangent planes each touching it along a plane curve (in fact, a circle), gave to Sir W. R. Hamilton the theory of conical refraction. The wave surface is now regarded in geometry as a particular case of Kummer's quartic surface, with sixteen conical points and sixteen singular tangent planes.

My imperfect acquaintance as well with the mathematics as the physics prevents me from speaking of the benefits which the theory of partial differential equations has received from the hydrodynamical theory of vortex motion, and from the great physical theories of electricity, magnetism, and energy.

It is difficult to give an idea of the vast extent of modern mathematics. This word "extent" is not the right one. I mean extent crowded with beautiful detail—not an extent of mere uniformity, such as an objectless plain, but of a tract of beautiful country seen at first in the distance, but which will bear to be rambled through and studied in every detail of hillside and valley, stream, rock, wood, and flower. But, as for anything else, so for a mathematical theory—beauty can be perceived, but not explained. As for mere extent, I might illustrate this by speaking of the dates at which some of the great extensions have been made in several branches of mathematical science.

And, in fact, in the address as written, I speak at considerable length of the extensions in geometry since the time of Descartes, and in other specified subjects since the commencement of the century; these subjects are the general theory of the function of an imaginary variable; the leading known functions, viz., the elliptic and single theta-functions and the Abelian and multiple theta-functions; the theory of equations and the theory of numbers. I refer also to some theories outside of ordinary mathematics: the multiple algebra or linear associative algebra of the late Benjamin Peirce; the theory of Argand, Warren, and Peacock in regard to imaginaries in plane geometry; Sir W. R. Hamilton's quaternions, Clifford's biquaternions, the theories developed in Grassmann's "Ausdehnungslehre," with recent extensions thereof to non-Euclidian space by Mr. Homersham Cox; also Boole's "Mathematical Logic," and a work connected with logic, but primarily mathematical and of the highest importance, Schubert's "Abzählende Geometrie" (1878). I remark that all this in regard to theories outside of ordinary mathematics is still on the text of the vast extent of modern mathematics.

In conclusion I would say that mathematics have steadily advanced from the time of the Greek geometers. Nothing is lost or wasted; the achievements of Euclid, Archimedes, and Apollonius are as admirable now as they were in their own days. Descartes' method of co-ordinates is a possession for ever. But mathematics have never been cultivated more zealously and diligently, or with greater success, than in this century—in the last half of it or at the present time; the advances made have been enormous, the actual field is boundless, the future full of hope. In regard to pure mathematics we may most confidently say:

> "Yet I doubt not through the ages one increasing purpose runs,
> And the thoughts of men are widened with the process of the suns."

CHAMPONNOIS'S STEAM STARCH PLANT.

The manufacture of starch requires, as well known, very many operations, which succeed one another, almost all of them, uninterruptedly and require constant surveillance. In the first place, it is the washing and cleaning of the tubers, which is required to be done with a certain energy, very rapidly, and not without the use of considerable water; and then it is the rasping and the elutriation, which, to be satisfactory, must be repeated in order to extract the maximum of product. It is necessary after this to collect the starch, to wash it in water, bleach it, dry it, bolt it, and put it into bags, while, on the other hand, it is necessary to receive the pulps, mix them, and wash and press them in order to extract therefrom a portion of the water that they contain, so as to render them fit to be used for feeding cattle.

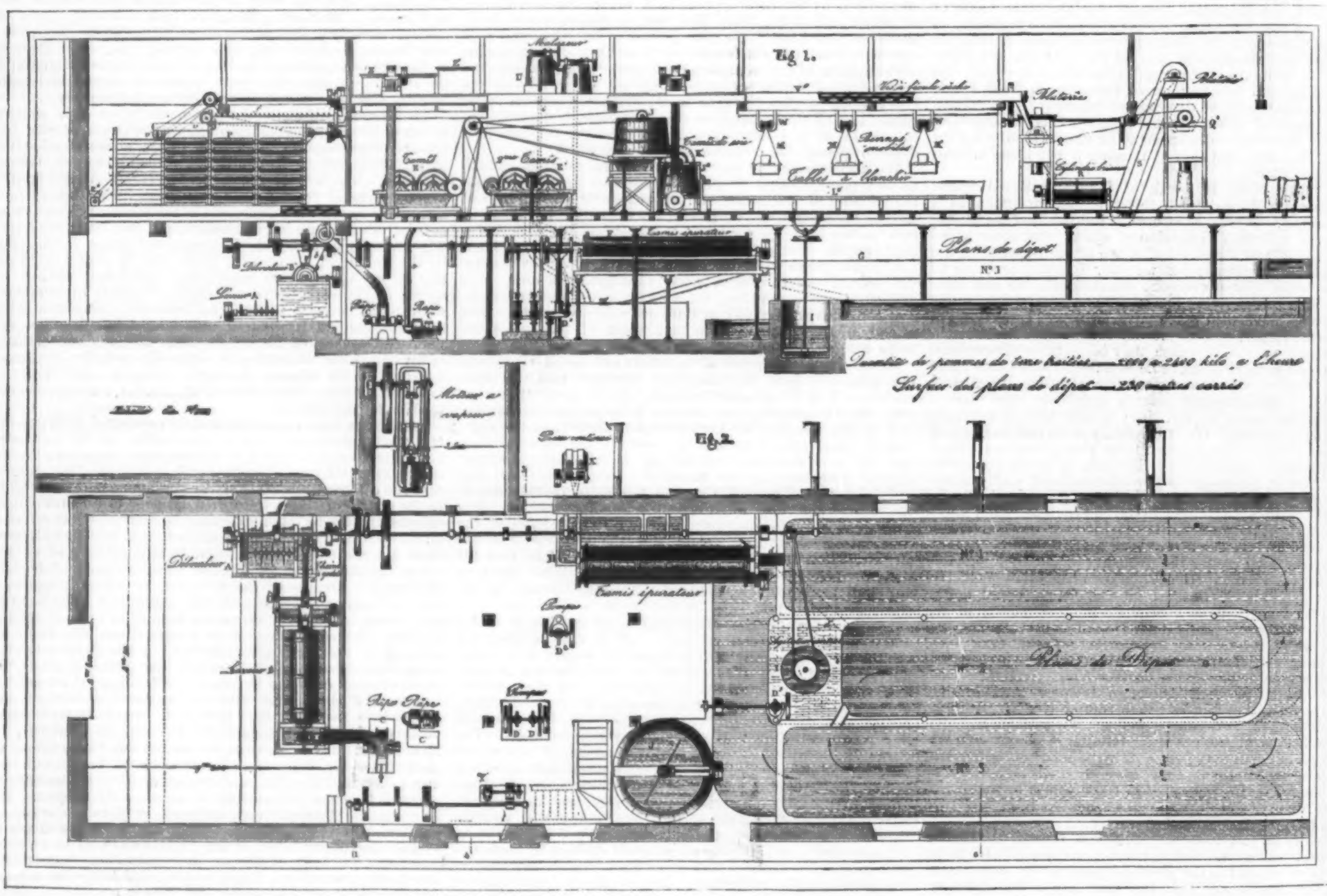


Plate I.—DETAILS OF STEAM STARCH PLANT AT MAGNEUX-LE-GABION, FRANCE.

In order to co-ordinate these different operations rationally, in a given place, with little manual labor, it becomes indispensable to study in advance the best arrangements to be adopted, so as to avoid all miscalculations that might work to the injury of the manufacturer.

A properly arranged factory may make the fortune of its proprietor, while if certain points be neglected it may cause his ruin. To-day, in fact, competition is such in the different industries, that the majority of them are enabled to exist only by force of economy, and by the minutest care taken in regard to the least details.

What we state in regard to the *materiel*, properly so called, of the factory, applies equally to the motor itself, which should not only be of a sufficient power to run all the machinery without trouble and with safety and regularity, but should also be so constructed as to consume a minimum of fuel and to require but slight cost to keep it in repair.

It is well to look ahead, too, at the time of starting the factory, to its possible enlargement, and to calculate the motive power as a consequence thereof. A well constructed steam engine of large proportions, with condensation and variable expansion, permits this end to be attained within certain limits, especially if care be taken to give the generator such dimensions that the heating surface notably exceeds that which corresponds to the nominal power.

In presenting herewith general views of the apparatus used in the starch works of Mr. Joseph Gaudet, at Magneux-le-Gabion, France, and devised by Mr. Champonnois, we deem it necessary to accompany them with some observations and accurate information that may prove useful in factories like this that are designed to work automatically in nearly all their parts, and with the co-operation of as few men as possible.

General Description of the Plant.—(Figs. 1 to 6.) Fig. 1 gives a longitudinal view of the building and a general elevation of most of the apparatus. Fig. 2 gives a general plan,

showing the place occupied by each apparatus on the ground-floor of the factory. Fig. 3 of Plate II. shows a second general plan of the different apparatus in the first story. Fig. 4 is a transverse section of the building made on the line 1-2 of the plan, and shows on the ground-floor the end of the cleaning apparatus, A, and a lateral elevation of the washing apparatus, B, and on the first story the automatic steam-drying room, P, with the elevator, O, that receives the dried starch. Fig. 5 gives a second transverse section on the line 3-4, looking in an opposite direction from the former, and shows the respective positions of the bolting apparatus, E, E', and F, the pumps, D and D, the vats, J and J', and the malaxators and pulp press. Fig. 6 is a third transverse section on the line 5–6, parallel with the preceding, showing the arrangement of the sediment planes, G, on the ground-floor, and the receiving and bolting apparatus for the dried starch, on the first story.

Cleaning and Rasping.—The potatoes are thrown into the cleaning apparatus, A (Fig. 1), where they remain sufficiently long to become freed from the greater part of the adhering sand and dirt; then they are carried by a chain and buckets, *a*, and emptied into the stone cleanser, B, which removes the gravel and small stones that have been carried along. From thence they are carried by a second elevator, *b*, to the coarse rasp, C, which revolving with extreme velocity, divides each tuber into thousands of very fine fibers so as to open all the cells.

The action of the cleaning apparatus is so effective that when half-rotten potatoes are put into it all the bad portions are reduced to a pulp and carried out with the dirty water. As a consequence, they never reach the rasp. The buckets of the elevators have the capacity of one cubic meter, and contain several apertures to allow of the passage

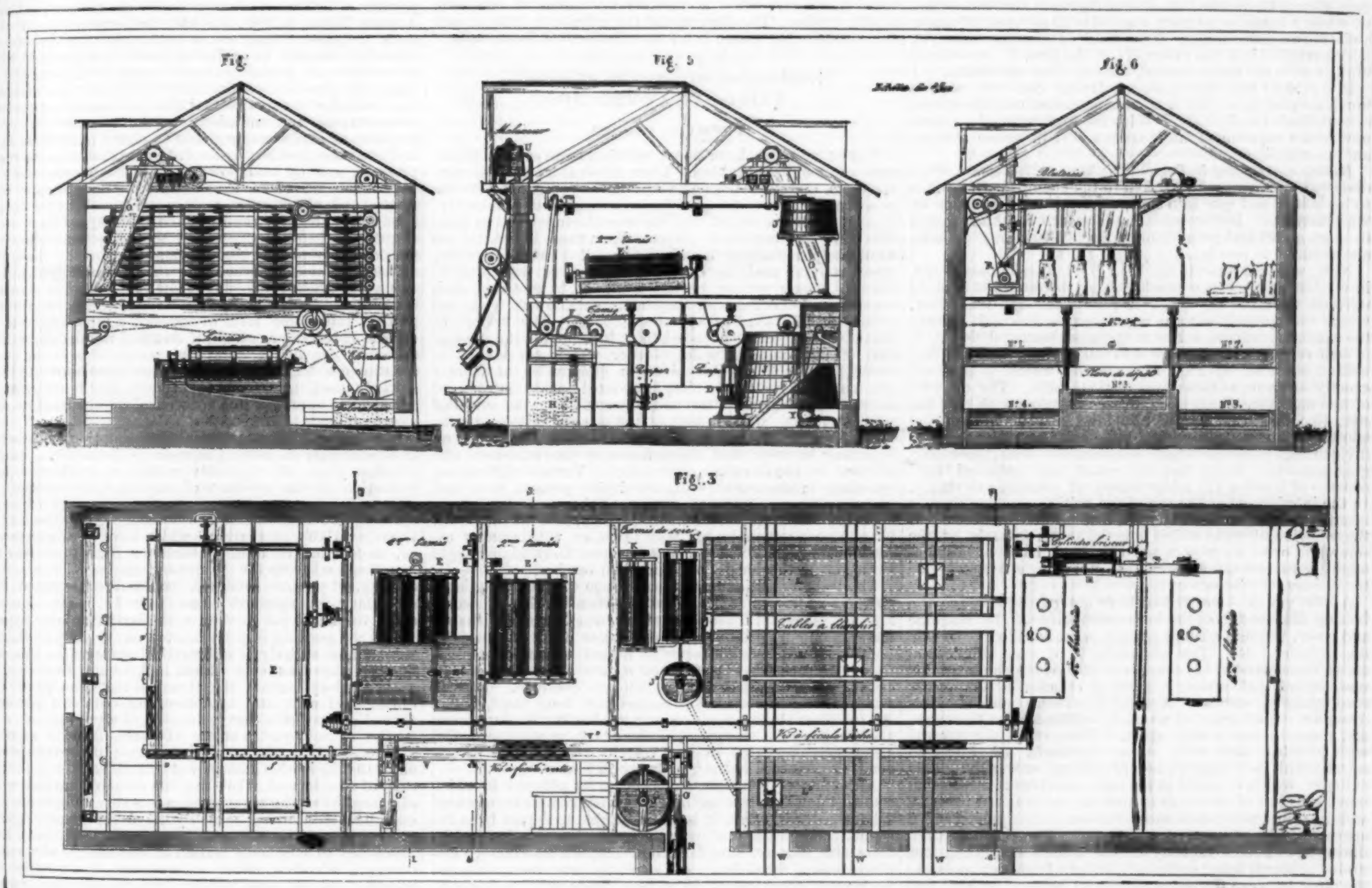


PLATE II.--DETAILS OF STEAM STARCH PLANT AT MAGNEUX-LE-GABION, FRANCE.

of the water in excess. They run at a speed of one meter per second. On pouring water directly into these buckets the washing of the tubes is completed, and the latter come out extremely clean. With such apparatus it is rare that stones or other hard bodies reach the rasp. The makers have given this last-named apparatus a diameter of 0·70 m. and a width of 0·20 m.

Elutriation.—A lift-pump, D, on the ground floor raises, through a sub-soil pipe, all the raspings charged with water and sends them directly into the two cylinders of the first metallic sieve, E, in the first story (Fig. 1). This sieve separates the granules of fecula from the pulp and delivers them to a second and finer sieve, F, called a "pulp-strainer," where they are drained, washed anew, and freed from a great part of their fibrous matter, in order to enter large flat backs, G, called "sediment planes."

During this time all of the coarse pulp coming from the first sieve is led by a large pipe, *c*, to a second rasp, C', called a "Champonnois rasp" and having closer blades and finer teeth than those of the first. The object of this rasp is to divide the filaments and all other parts that have not been sufficiently acted upon at the first rasping into finer fibers, so as to extract therefrom every bit of fecula that they may contain. A second lift-pump, D', raises all the products of this second rasping to the two metallic sieves, E', which are arranged like the others on the floor of the same story. These sieves likewise separate the pulp from the fecula, as in the preceding operation. The pulp falls directly into the lower reservoir, H, while the granules of fecula are carried to the pulp-strainer, F, which thus receives at once all the products of the two raspings, save the eliminated pulp.

The two first sieves, E and E', are double, and their cylinders, which are hexagonal, are 3 meters in length, with sides 0·34 m. in width, thus possessing, each of them, a filtering surface of 4·308 square meters.

The fecula coming from the pulp-strainer is directed into the backs, G, while the pulp falls into the lower reservoir, H, from whence it is taken up by a third pump, D^2, and forced to the continuous press, which extracts a portion of the water that it contains.

It may be easily seen from what precedes that in this multiple operation of cleaning, double rasping, and triple elutriation the hand of man in no way intervenes. From the time the workman shovels the potatoes into the cleaning apparatus, all the work is effected automatically.

The Backs or Sediment Planes.—These vessels, in which are deposited all the starchy matter, are here five in number. The first two, designated by the numbers 1 and 2, are parallel with one another and almost on a level, and at about the height of a man above numbers 4 and 5, which are on a level with the ground-flow of the factory. These four backs are separated by an intermediate one, No, 3, which, situated half-way between the others, forms the third plane, properly so called.

The fecula enters back No. 1 through the pipe, *d*, and settles therein, while the supernatant liquid flows out through a rectangular opening into back No. 2. This opening is regulated by small angular gates that become superposed, one on the other, in measure as the filling of the back proceeds, so as to always produce an overflow of the liquid in a very thin stream.

Back No. 2 is connected with No. 3 in nearly the same way, save that the latter, being beneath the former, an oblique conduit is added outside of the communicating orifice to carry the excess of liquid still containing starch into the third back during the whole period that the two first are operating.

From this third back or plane the liquid passes, when need be, into the fourth, then into the fifth, and from thence into the external vessels.

When the two first sediment planes are sufficiently full, that is to say, when the layer of fecula that has settled therein has a thickness of 25–30 centimeters, they must be emptied. To do this, communication between the pulp-strainer and plane No. 1 is interrupted by closing the extremity of the conduit, *d*, and another is set up, through the pipe, *d'*, with plane No. 3, provided, as presumable, the latter is not full; and this then supplies planes Nos. 4 and 5. In this way there is no interruption in the operations of rasping and elutriation.

To take out the accumulation of starch, the workman runs off the excess of water that covers the latter, cuts out the starch in blocks by means of a spade, and carries these in a wheel-barrow to the cylindrical vessel, I, which stands at the head of the third plane and is called the "Central agitator." In the center of this vessel there revolves a vertical axle that carries at its lower part a strong rake provided with iron teeth designed to break up the lumps of starch, mix them, and reduce them to a pap by the aid of a current of clean water. This pap, in a very dilute state, is forced by a fourth pump, D^3 (exactly like the others), either into a large vat, J, or directly into the additional vat, J', placed in the first story, at a proper height to supply by pressure the silken sieves, K and K', and, if need be, both of these at the same time.

When the third back is to be emptied, the two first are already empty, so that it is possible to send to No. 1 the fecula from the pulp-strainer. It is necessary then to put the extremity of No. 2 in communication with the head of No 5, until the third back has been emptied in its turn. After this the entrance of starch into the first back is stopped, a communication of the strainer with No. 3 is set up, and the latter thus becomes No. 1, while backs Nos. 4 and 5 take the place of Nos. 2 and 3.

At the works under consideration the sediment-planes have a superficies of 230 square meters, and the supplementary planes are 60 meters in length by 1 and 2 in width, thus adding a surface of 180 square meters. From these latter backs the water falls into two large safety pits that collect the last particles of fecula mixed with impurities. These two pits, which are located near each other, communicate through their upper part, and, when they are both full, the excess of liquid, completely divested of fecula, flows off through drains into the fields, which latter it waters and fertilizes.

Bleaching of the Starch.—The feed-vat, J', on receiving the well triturated and diluted fecula, either from the agitator, I, or the reservoir-vat, J, empties it, through pressure, into the first sieve, K, which is provided with No. 120 silk, and communicates with the second sieve, K', whose finer silk is No. 150 or 160. Thus twice elutriated, it is distributed over one of the two tables, whereon there deposits a very white starch nearly free from small fibers. As soon as the table is full (which will be in the course of 6 to 8 hours), the product of the sieve is passed to the other table, which has been previously prepared and cleaned to receive it. The work of cutting the layer into blocks and removing it from the first table is performed by two men with the aid of movable skips, M, suspended beneath small rolling carriages, W, that render the transfer quick, clean, and economical.

When there is need of haste, the two silken sieves operate separately and empty their products at once upon one of the tables, L, L', which becomes full so much the quicker in proportion as the fecula is compacter and denser. As it sometimes happens that the portions near the lower extremity are softer, and are darkened by small fibers, they must be washed anew. In this case they are thrown through an aperture in the floor into the large vat, J, and then carried up again to the sieves, or else they are carried to the small additional vat, J^2, which, like the preceding, is provided with an agitator, and receives like them a stream of clean water. From this vat the material can, at will, be passed into the second filter, or directly upon the third bleaching table, L^2.

Hydro Extraction.—At the beginning of desiccation much time is lost; since, in spite of the quantity of air sent by the heating apparatus to the drying room above, it takes several days to extract 5 to 6 per cent. of water; and we know that the starch coming from the bleaching table contains as much as 50 per cent., and that it is necessary to remove at least 10 per cent. of this before sending it to the drying-room.

At Palinges, hydro-extractors are preferred, although they require considerable motive power. The operation is as follows: The green fecula coming from the bleaching tables is thrown into a vat that contains an agitator, and is therein triturated, mixed afresh with water, and sent in a liquid state into the drum of a turbine one meter in diameter that makes 1,200 revolutions per minute. The object of the turbine is not only to dry the material, but also to separate the impure portions, such as the small fibers that are lighter than the starch. This latter on making its exit from the drier is carried by an endless screw to an elevator that empties it into the drying-room.

The operation of turbinage lasts from 4 to 5 minutes, and the drum holds about 100 kilogrammes of material. It requires two turbines, with two men to attend to them, in order to have as little interruption as possible in the work. It is estimated that these remove about 10 to 12 per cent. of water from the starch, so that when the latter is placed upon the shelves of the steam drying room, it contains but 38 to 40 per cent. at the most. This is satisfactory, although it cannot help being expensive. It would be desirable to

extract 15 to 16 per cent. of water, so that the drying room would have to effect less evaporation.

A quick process of drying starch is at the present moment under study at the Magneux works, and promises to give economical results.

Drying.—The hydro-extracted starch reaches the drying room, P, charged with a portion of the water that it contained, and can then be easily distributed by the movable conduit, *f*, over the endless cloths passing above and between the steam shelves. In the general views given in the accompanying plates are figured three series of endless cloths, the third being fed by a screw, *v*, added to the prolongation of the distributer, *f*, in such a way as to receive that portion of the material that it has not emptied upon the two upper cloths. This screw is also capable of emptying its own excess, when too great a quantity reaches it, upon another transverse screw, *v*, whose box contains several apertures closed by registers that permit of delivering to the workman in charge of the drying, the said excess of material and of spreading it over the cardboards at the extremity of the steam shelves. In this way there can be dried with certainty the whole product that reaches the drying room, even though it should arrive in greater quantity at moments when the feed is not very regular. As the layer of starch on the cloths is very thin (scarcely 15 to 20 millimeters) its desiccation takes place in from 1½ to 2 hours, while that on the cardboards, being thicker and irregular, requires 7 hours or more to dry. The starch dried on the endless cloths falls, on escaping from the lower one, upon an endless screw, V′, placed upon the floor, parallel with the rollers, and this carries it to the foot of the elevator, O, and this latter carries it up and throws it on to the long screw, V^2, called the "dry starch screw." The starch in excess which is dried upon the cardboards at the end of the shelves is taken up by the workman when it has reached the desired degree of desiccation (that is, when it contains no more than 24 to 25 per cent. of water) and thrown into a hopper at the head of another screw, v^2, which empties it at the extremity of the first, V′, in order to unite it with the starch coming directly from the cloths.

It is evident that this mode of drying does not require much manual labor, but it must be admitted that the system is complicated and costly. With the application of a system now under experiment at Magneux it will prove simpler and more economical.

Bolting and putting in Bags.—The long endless screw, V^2, is designed to carry the dry starch to the chamber where it is to be bolted and put into bags, so as to avoid carriage by wheelbarrows. Before bolting, the starch is either passed through a mill and ground, or through a breaking cylinder and reduced to powder.

Now, when the starch has been dried upon endless cloths, in very thin layers, it is much less agglomerated and is easily reduced to dust. So when it passes through the screw, which continuously agitates it, a large portion of it reaches the extremity almost as fine as the most beautiful flour. It is then very natural to cause it to fall directly into the first bolting machine, Q (Figs. 1, 3, and 6), which is arranged exactly the same as those used in flour mills. The cylinder of this machine, which is six sided, is covered with very fine silk, like that used in the bleaching sieves, the numbers adopted being generally 130, 140, and 150. The case is divided into three parts that communicate with three bagging apparatus to the base of which are attached bags capable of holding 125 kilogrammes of commercial starch. In the interior and at the top of the bolting machine there is inserted a sheet iron cylinder, O, 0·36 m. in diameter and of the same length (into which falls the starch brought by the screw), in order to protect the silk from hard bodies that might be carried along, and which, not being able to traverse the meshes, are thrown outside.

All the grains of starch that have not passed through the bolting silk issue from the lower extremity of the machine and enter, through a small hopper, what is called a "breaking cylinder," R. This apparatus is of very simple and cheap construction. It consists of a wooden drum mounted upon an iron axle which is given a velocity of 450 or 500 revolutions per minute. Around the external surface of this drum are nailed strips of wood, 45 millimeters in thickness, and spaced 5 centimeters apart. These strips are covered with punched sheet iron whose apertures are arranged spirally with their ragged edges projecting outwardly. This cylinder, which is closed at the ends, revolves in a wooden box consisting of two semi-cylindrical parts united by bolts and lined internally with sheet iron containing jagged edged apertures like those of the cylinder. The result is that, during the extreme rapidity of the drum's revolution, the grains of starch being constantly thrown from one point to the other between the sheet iron are so beaten, broken, and pulverized that they reach the other end of the machine almost entirely reduced to powder. An elevator, S, placed at this extremity, receives all this powder and empties it into a second bolting machine, Q, which is arranged like the other, and furnished with silk of the same number, and with bagging machines externally.

It will be seen that by this arrangement there is secured a minimum in manual labor, since one man suffices to oversee the entire operation of bolting, to remove the full bags and replace them by empty ones, remove the portions that have not been bolted, weigh the bags in measure as they are filled, and tie them up so that they can be stored.

Pressing the Pulp.—As we have above stated, all the exhausted pulp derived from elutriation falls into a reservoir, H, on the ground floor. From this it is taken up by a special pump, D^2, which, before forcing it to the press, sends it through a pipe, *i*, to a malaxator placed at the upper part of the factory, as shown in Figs. 1 and 5.

This machine is double, that is to say, is composed of two cylindrical iron plate vats, U, U′, 0·82 m. in diameter by 0·90 m. in height, placed so that one is higher than the other, in order that the overflow of one may fill the other through a communicating pipe. Each of these cylinders contains an agitator consisting of a vertical axis provided with inclined paddles passing between fixed and shorter blades riveted to the inner sides of the vessel. Motion is given by a pulley fixed to the axle which drives the first agitator through a pair of small bevel wheels, and is transmitted by two spur-wheels fixed to a second and parallel axle, which, in the same way, drives the second. An overflow pipe is adapted to the upper part of the latter to carry the excess of pulp over into the lower reservoir. The pulp, passing successively from one vat to the other, is carried, after this double malaxation, through a vertical pipe, *j*, to the cylinders of the continuous press, X.

This press is fed automatically, and so regularly that the ribbons of pulp issuing from the cylinders are of equal thickness and always contain nearly the same quantity of water.

Water Pump and Reservoir.—As may be seen from what precedes, it takes a large quantity of water to satisfy all the needs of a starch factory. The constructors have adopted, for this reason, a strong, horizontal, continuous pump, Y (Figs. 2 and 5). This runs at a normal speed of more than 160 to 200 revolutions per minute, and is capable of furnishing 25 cubic meters of water per hour. This water is forced into two iron plate reservoirs, Z, placed under the roof of the building, for supplying, on the one hand, the steam boiler, and, on the other, the washing machines, the rasps, the sieves, the central agitator, the vats, etc.

The Steam Motor.—The motor at the Magneux works is a high pressure engine, with variable expansion, of the system of Mr. C. Jouffray, of Vienna. This system is particularly distinguished by its mode of distribution through two slide-valves adapted to the extremity of the cylinder, and by the ingenious application of a double expansion mechanism run directly by the very sensitive governor. This arrangement permits of reducing dead spaces as much as possible, of consequently avoiding a loss of steam at each end of the stroke, and of obtaining a constantly normal speed.

The generator is tubular, with internal furnace. The external shell is 1·6 m. in diameter by 4·2 m. in length, and is surmounted by a dome 1 m. in height and 1·1 m. in diameter. The inner shell is 0·9 m. in diameter, and runs 0·83 m. back of the furnace, thus giving a length of 5·13 m. The tubes, which are 44 in number, are 0·07 m. in diameter. In sum, the total heating surface of this boiler is more than 35 square meters, which supposes that it is capable of producing the steam necessary for supplying an engine of 30 H. P. or less. This boiler, however, has been calculated for a normal power of 25 horses in running 50 revolutions per minute, although its dimensions are such that it may, without fear, be driven beyond this, since the expansion is capable of varying from nine-tenths up to half the stroke, that is to say, with a variable admission of one-tenth to five tenths. The diameter of the cylinder is 0·35 m. and the stroke of the piston is 0·7 m.—*Publication Industrielle.*

[Concluded from Supplement No. 406, page 6473.]

EXPLOSIVE COMPOUNDS.

PRISMATIC POWDER.

These powders have one somewhat large central perforation to facilitate ignition. Their external hardness is considerable, and their density very high as compared with the powders for heavy guns which were known until recently. It need hardly be stated that the manufacture of these powders differs in important respects from those in general use until lately, including the largest so-called pebble powder, which were all made by breaking up cakes or slabs of powder into masses, within certain limits as to size, and then removing the edges and imparting smoothness to the exterior by the so-called glazing process. The system of manufacture of our new powders is in principle the same as that of the so-called pellet powder, which was devised in 1860 by a War Office Committee on gunpowder, of which I was a member (being the first large-sized powder introduced into our service, and afterward superseded by the so-called pebble powder), and as that of the original prismatic powder, which Russia derived at about the same time from an American inventor, and which was some time afterward also adopted by the German government. Various difficulties, especially in connection with the drying process, have had to be overcome in the production of these very large powders, so as to attain sufficient uniformity, and the process of blending has to be adopted with them, as with smaller natures of powders, so as to counterbalance unavoidable slight variations in the density of individual batches.

The Italians still adhere to the system of producing large powders which we are abandoning—namely, that of breaking up cakes into necessarily somewhat irregular shaped masses; but by producing these cakes from mixtures of powder of different character in regard to inflammability, they have succeeded in attaining results which are at least equal to the best that we have hitherto obtained. Thus in some experiments made at Spezia, not long since, with a 100-ton breechloading gun, constructed by Sir W. Armstrong and Company, a charge of 771 lb. of this powder propelled a shot weighing 2,005 lb. at a velocity of 1,833 feet per second, the pressure in the gun being 16·5 tons.

Although the principle has been so far adhered to which was laid down in 1858 by the gunpowder committee to which I have referred, that it is not desirable to depart from the normal composition of powder unless modifications of its form, size, density, etc., fail to accomplish satisfactory modifications of the violence of its action, some interesting and instructive experiments have been made with powders in which the proportions of sulphur and charcoal have been considerably modified, especially with the object of ascertaining whether the mechanical injury to the inner surfaces of guns, resulting from repeated firing of heavy charges—in other words, the erosion of the bore—could be diminished by such modifications. That this erosion is not primarily, or, indeed, to any considerable extent, ascribable to the chemical action of the sulphur in powder upon the steel surface, at the high temperatures developed, appears to have been conclusively demonstrated by those experiments; the ballistic results obtained with some powders differing widely in regard to their proportions of saltpeter, charcoal, and sulphur did not encourage the belief that modifications in that direction would furnish favorable results.

COCOA POWDER.

It has, however, been recently demonstrated by experiments with some of our heavy guns, as well as by trials in Germany, that a very wide departure from the usual composition and structure of powder masses, a departure so wide as to yield a powder which would be absolutely worthless in guns of small caliber, may furnish a propelling agent which is not only suitable for heavy guns, but which gives results as regards the development of high velocities, accompanied by moderate pressures, comparable with some of the best which have been obtained with our newest large powders of normal composition. A powder, christened "cocoa powder," on account of its peculiar brown color, which is now manufactured in Germany, and has furnished these satisfactory results, contains a comparatively high proportion of a carbonaceous material very different in character from the charcoal used in powder manufacture; the proportion of sulphur in it is below 3 per cent., and it contains, thoroughly incorporated with the other ingredients, a small proportion of a resinous substance, which doubtless exerts a very decided influence upon the rate of its combustion. One effect of the uniform distribution of this resinous body throughout the powder masses is to give them the property of entirely resisting disintegration during long periods of immersion in water. The impregnation of the surfaces of powder masses with paraffin or wax has been applied with some success to impart to them increased power of resisting deterioration by the absorption of water from a moist atmosphere; but this treatment has not commended itself, because of the increase in the residue or fowling of powders when thus treated. The distribution of the resinous matter throughout a mass of the cocoa powder does not, curiously enough, diminish its hygroscopic properties. On the contrary, the tendency of this powder to absorb moisture is somewhat greater than that of powder of similar size and density but of normal composition. It remains to be seen whether these are superior to the cocoa powder as regards uniformity of action, or the extent to which they act injuriously on the gun's bore; but so far as experiments have been carried, this greatest novelty in powder manufacture has, at any rate, afforded very instructive additional demonstration of the important differences which considerable increments in the quantity of a charge bring about in the conditions under which powder, confined in a gun by the projectile, undergoes transformation. Just as, on the one hand, a powder of normal composition, but of a size and density suitable to furnish excellent results, with perfect safety to the gun, in artillery of small caliber, acts very destructively when used in the corresponding proportion calculated to furnish useful results in guns of large caliber, so, on the other hand, gunpowders which, either by virtue of their composition, or the size, form, and density of their masses, are quite unsuited to furnish any useful results with small guns, will, when submitted to conditions favorable to their action as regards the initial pressure and heat developed by the ignition of large charges, furnish high ballistic results, and without detriment to the stability of the arm.

METAMORPHOSIS OF POWDER.

The results of the researches on the action of fired gunpowder, which were commenced by my colleague, Captain Andrew Noble, in 1868, and have been carried on by us two up to the present time, and in the course of which we have exploded charges of different powders, ranging in weight up to 20 lb., in perfectly closed vessels, collecting and analyzing the products formed (but which have also included a large number of experimental observations with guns), have demonstrated the variations in the composition of the products of explosion furnished in closed chambers, by one and the same powder, under different conditions as regards pressure, and by two powders of similar composition, but differing in size of mass, when fired under the same conditions as regards pressure, and so considerable that no practical value whatever can be attached to any attempt to give a general chemical expression to the metamorphosis of a gunpowder of normal composition. Berthelot, whose views on such subjects as these are entitled to the greatest consideration, chose to assume from the foregoing statement, made in our first memoir, that we denied the possibility of putting into some form of equation a representation of a variety of reactions, which, if assumed to take place simultaneously among the different proportions of the powder constituents, might give approximate expressions to the results obtained in any one experiment, and might, thus far, afford some approach to a theoretical representation of the metamorphosis of gunpowder.

Starting with this unwarranted assumption, he proceeded in an elaborate theoretical memoir to demonstrate that the simplest form of expression which he could give to the formation of the products of explosion of powders, in a closed chamber, consisted in the incorporation of nine or ten distinct reactions assumed to occur simultaneously, but in very variable proportions, which have to be supplemented, according to him, by three or four other chemical equations, whereby the formation, during the process of cooling, of certain products, believed or assumed to be secondary, is explained. Last year Dr. Debus communicated to the Royal Society a similarly elaborate paper, of which the portions directly bearing on the subject discussed were almost entirely of a theoretical nature. In this paper he propounded a theory which, in his view, explained "in a satisfactory manner the chemical reactions which occur during and after the explosion, not only of a powder of normal composition, but, generally, of a mixture of x molecules of saltpeter, y atoms of carbon, and z atoms of sulphur." After the somewhat astounding preliminary remark that Berthelot had arrived at a different conclusion to that of Noble and Abel, that the chemical metamorphosis of gunpowder during explosion is a very complicated process (he would more correctly have represented our expressed view if he had said a very variable process), Debus proceeded to eliminate certain of our analytical results, as being, in his view, either unimportant, or exceptional, or incorrect; to add some results of other experimenters which are of entirely exceptional or abnormal character, but were suitable to collate with our results for the purpose of arriving at certain mean numbers; to exclude from consideration certain important facts, and to place what we believe to be inadmissible interpretations upon others; and, finally, to adopt the assumption that the combustion of powder takes place in two successive stages, and to base upon this assumption, and upon inferences arrived at as above indicated, the conclusion that three equations taken together express correctly the metamorphosis of powder when exploded in a closed space.

Our heavy official work has prevented us from submitting to the scientific world this season the detailed discussion of the theoretical considerations and conclusions put forward in the able paper by Dr. Debus, with which we are prepared; but I think the justice of our contention will be conceded, that however interesting the speculations submitted by Berthelot and Debus, and however valuable they may prove as intellectual training to the student, those eminent chemists have conclusively demonstrated the correctness of the statement made by us in 1874, that no practical value can be attached to any attempt to give a general chemical expression to the metamorphosis of gunpowder. So much important work has been done since the publication of my first memoir on explosive agents in 1869, in contribution to our knowledge of their nature and properties, and of the conditions determining and modifying their action and metamorphosis, that it is difficult for me to refrain from giving you a slight sketch of the valuable labors of Berthelot, Sarrau, Vieille, Roux, Champion, Pellet, and others in these directions, but I have already more than once, in these observations, been betrayed into forgetting the determination I had made to deal only with points of practical interest in connection with my subject. In this direction alone there is so much, not perhaps of novelty to most of my listeners, but of interest, I believe, to all, which I might still trench upon, that I hesitate as to whether I should not conclude my observations at this point, but feel it impossible to deal, however imperfectly, with the subject of explosives, without offering some remarks on the great progress made within the last few years in what now have become most import-

ant branches of chemical industry, the manufacture and application of nitro-glycerine and gun-cotton preparations, and on the causes of that progress.

EVOLUTION OF GUN-COTTON.

On the occasion when the Fellows of the Chemical Society accorded me, as their president, the pleasure of their company at Woolwich (and I believe that a large proportion of those I am now addressing were among my guests on that occasion), I endeavored, by means of a series of experimental demonstrations, of a kind or on a scale not to be attempted in the lecture room, even by Mr. Allen or myself, to illustrate the development of detonation in explosives; the conditions to be fulfilled for its development and transmission; the velocity with which it is transmitted from one mass to another along great distances, and even across small intervening spaces; its transmission through considerable intervening spaces by the agency of tubes; the great differences in point of sensitiveness to detonation between different explosive compounds; the want of reciprocity between different explosives in regard to the readiness with which one is detonated by the other; the effect of confinement in developing detonation; the influence of the mechanical or physical characters of an explosive upon its susceptibility to detonation; the difference between detonation and what the French now call explosion of the second order; and some other points of importance in the scientific consideration and practical application of so-called detonating agents. Many of my illustrations were carried out with gun-cotton, and I embraced the opportunity to furnish demonstrations of the one especially valuable quality of compressed gun-cotton, namely, that while it may be preserved unchanged for any length of time, and even without detriment to its mechanical condition or density, and consequent efficiency, when thoroughly saturated with water, in which state it is absolutely uninflammable, it may be detonated in that condition, with destructive effects at least equal to those obtained with the air-dry material, through the initiative agency of a sufficiently large confined charge of mercuric fulminate, or of a comparatively small amount of air-dry compressed gun-cotton, detonated in the usual way. I must not stop to discuss the theoretical explanation of this remarkable property, of the reasons why a mass of compressed gun-cotton, the interstices of which are filled with a liquid, should be in a condition more favorable to the rapid transmission of detonation from particle to particle than if those interstices were filled with air, as in dry gun-cotton, or of the reasons why compressed masses of mixtures of finely divided gun-cotton with nitrates should be as sensitive to detonation as pure compressed gun-cotton, while masses in which the nitrate is replaced by chlorate are even more sensitive. These various subjects, and many others relating to the history of explosive agents, were for the first time discussed in my memoirs of 1869 and 1874, published in the Royal Society's *Transactions*.

The absolute stability of gun-cotton when kept wet, the great simplification of all ordinary arrangements connected with its storage and transport in that state, owing to its non-inflammability, and the very important diminution of possible sources of danger in its application, have combined to endow wet gun-cotton with special advantages for all military and naval purposes for which violent explosives are valuable, as for submarine mines and torpedoes, and for other engineering purposes connected with siege and field operations, such as the hasty demolition of works and buildings, the blowing in gates and palisades, etc., in operations of attack, the interruption or demolition of railways, and the rapid destruction or disablement of guns, in many of which directions very valuable work was done by gun-cotton during the recent operations in Egypt. Large stores of wet compressed gun-cotton exist at all our naval stations, and we continue to manufacture fresh supplies from year to year at our government works at Waltham Abbey. The French have also adopted compressed gun-cotton for the naval and military service purposes to which I have referred, and they have a factory at Moulin-Blanc arranged upon our system. The German government was furnished, some years ago, with working drawings of our plant, and handed them over to a private firm, who established works in Silesia, from which the military and naval requirements of the government are met; and copies of these drawings found their way to Russia, where, I believe, Abel's gun-cotton is also manufactured.

The gun-cotton works at Stowmarket, which have passed through several changes of fortune since the disastrous explosion of 1871, are now in the hands of a company who combine the production of ordinary compressed gun-cotton with that of small arm powders, more particularly sporting powders, in which nitrated gun-cotton is the basis, the material being converted into hard granules of suitable size and uniform quality by a very simple process. This powder (known as E. C. powder) has entered into competition with the so-called Schulze powder, the nitro-cellulose in which is prepared from wood fiber. The original Schulze powder, invented by an officer of the Prussian artillery more than twenty years ago, consisted of small fragments of very regular size, of wood, which, after partial purification, were converted into an imperfect nitro-cellulose, and afterward impregnated with potassium chlorate, or a mixture of it with saltpeter. This powder soon found considerable favor with sportsmen, though it lacked uniformity, and was occasionally somewhat violent. It has been improved upon from time to time by the makers, and the granulated powder, of very uniform appearance, which is now extensively manufactured and apparently much liked, bears considerable external similarity to the E.C. powder. I was recently informed by the makers that its consumption is extending very rapidly, the sales having been in 1881 as much as 107 per cent. in excess of those of 1880, and last year 80 per cent. in excess of those of 1881. The comparative cleanliness, absence of smoke, and diminished recoil attending the use of these nitro-cellulose powders are strong recommendations in their favor to sportsmen, and they appear greatly in advance, in point of uniformity and general freedom from distressing effect upon the rifle, over the earlier gun-cotton cartridges. Their possible successful competition with military rifle powders is, however, as yet quite an open question.

The circumstance that compressed gun-cotton *per se* tends, upon explosion, even in thoroughly sound and well tamped blast holes, to vitiate the air in underground workings and badly ventilated places much more injuriously than nitro-glycerine preparations, on account of the somewhat considerable proportion of carbonic oxide evolved from it, constitutes one important reason why it should not find favor as a blasting agent. The same objection does not apply to compressed mixtures of finely divided gun-cotton with the proper proportion of a nitrate, and the results of extensive experiments, made under my direction ten or twelve years ago, established the value of such preparations as mining and blasting agents. Nitrated gun-cotton, for the nitration of which barium nitrate has been selected, for reasons which I need not discuss here, finds a somewhat extensive sale now in some mining districts, and, I believe, in the colonies. As the term "nitrated gun-cotton" would scarcely have given an air of novelty to this preparation, it was introduced to the mining world some years ago under the name of tonite, and more recently under the designation potentite.

NITRO-GLYCERINE.

So far as progress in commercial success is concerned, the career of gun-cotton has been a very checkered and modest one as compared with that of nitro-glycerine. Brought into the world very shortly after Schönbein's gun-cotton wool, and regarded for seventeen years simply as a chemical curiosity of highly dangerous and very unstable character, the development of its industrial importance has been steadily continuous since first Alfred Nobel solved the problem of its successful practical application and its manufacture upon a commercial scale. It will be generally conceded that the resolve to attempt the production of about half a ton of nitro-glycerine in one single operation presented a display of great courage which would have been deemed sheer recklessness had not success demonstrated that every detail and every conceivable source of danger had been first carefully gone into, and every possible contingency effectually provided against. Comparatively recent experience at factories not under Nobel's direction has failed to demonstrate that any advantage in point of quantity and quality of product or safety is gained by carrying out the nitrifying process in small distinct operations. On the other hand, a supposed improved process, devised by M. Boutmy, and adopted at the French Government works at Vonges, where I recently had an opportunity of inspecting the working of it (and the novelty in which consists in first mixing the glycerine with a proportion of the oil of vitriol used in the converting operation, the nitro-sulphuric mixture being afterward added to this when cool), possessed grave defects, very liable to become sources of danger, besides being decidedly inferior as a commercial process, on account of the length of time needed for obtaining a yield approaching that which is furnished by Nobel's quick process. A very serious explosion, fortunately unattended by loss of life, occurred last autumn at the works of the Explosives Company at Pembrey, in South Wales, in an attempt to carry out the Boutmy process upon a large scale, but it can scarcely be said to have been due to the effects of the process itself.

DYNAMITE.

Although, from information furnished me some time since, there appears no doubt that even before 1854 General Picot had applied detonation to the explosion of gunpowder charges, with considerable advantage as regards increased violence of action, the merit must be admitted to belong to Nobel of having been the first to examine the effects of an initiative detonation in developing the detonation of nitro-glycerine, the violent explosion of which it was very difficult to bring about by the ordinary methods of applying flame or heat, and there is no doubt that the success of his subsequent work in this direction led to the general application of the system of explosion by detonation. Although nitro-glycerine in the liquid state was somewhat extensively used for a brief period, its employment, even with the aid of detonators, was attended with uncertainty, the liquid having a tendency to escape detonation, for reasons which have been explained in my earlier memoirs, while the transport and handling of nitro-glycerine were accompanied by dangers very difficult to guard against. An enormous stride was therefore made in the utilization of nitro-glycerine when Nobel first applied it in the form of the plastic preparations known by the generic term of dynamite, of which the kieselguhr dynamite has hitherto been decidedly the best, because the silicious earth, when fairly pure and properly calcined, will hold as much as three times its weight of nitro-glycerine absorbed, forming with it a putty-like mass, from which the liquid has very little tendency to separate, even when the mixture has been frequently exposed to alternate heat and cold. Until recently, kieselguhr was obtained entirely from abroad, but considerable beds of good quality have been discovered in Aberdeenshire, forming in some places the bottom of peat mosses, and the dynamite works at Ardeer are at present supplied largely from that source.

Dynamite has now been so long in extensive use that its properties are familiar to all who have paid any attention to the application of explosives. In point of convenience its plasticity gives it decided advantages over rigid cartridges, like compressed powder or gun-cotton, or tonite, on account of the greater facility of loading blast holes with it, while, in point of power, kieselguhr dynamite, containing 75 per cent. of nitro-glycerine, is, in most kinds of work, about equal to pure compressed gun-cotton. In the open air its detonation is a little sharper than that of the latter. In experiments with long trains (continuous and spaced) of compressed gun-cotton, dry and wet, and of dynamite, which I made some years ago, with the aid of Captain Noble's chronoscope, I found that detonation was transmitted by dry compressed gun-cotton at the rate of between 17,000 feet and 18,000 feet per second, by wet gun-cotton at between 19,300 feet and 19,900 feet per second, and by Nobel's kieselguhr (No. 1) dynamite at the rate of 20,000 feet to 24,000 feet per second. Mr. McRoberts, the talented director of the dynamite works at Ardeer, states that a ton of dynamite cartridges of the usual size (⅞ inch diameter), laid out in a line end to end, would extend one mile. According to the foregoing results, this train of cartridges would be entirely exploded in one-quarter of a second, if detonated at one extremity.

One defect of nitro-glycerine and its preparations consists in the facility with which the liquid freezes, at about 40° F., and its comparative inertness when in the frozen condition. If a cartridge of frozen dynamite is ignited it burns very slowly, the thawing of the cartridge proceeding in advance of the combustion, and it has not been unfrequently observed, when several cartridges of hard-frozen dynamite are ignited in a heat, that the slow combustion of a portion is followed after a time by a violent explosion of the remainder, which may be due to the fact of some small quantity of the nitro-glycerine being heated up to the exploding point during the slow combustion of surrounding portions, especially if the part which thus becomes heated is inclosed in some of the still frozen dynamite, which, acting like a shell, intensifies the explosion. The thawing of frozen dynamite, or other nitro-glycerine preparations, is a necessary preliminary to its use in blasting, and although very simple and safe instructions are disseminated for performing this operation, the majority of accidents that occur with dynamite in the mining districts are due to incautious treatment of the frozen material. A very disastrous accident which occurred last November at the new dynamite factory at Pembrey, belonging to the Explosives Company, Limited, afforded fresh proof of the imperative necessity for the systematic compliance with effective precautions for guarding against the freezing of nitro-glycerine and dynamite, and for dealing with the latter when frozen.

Nobel originally produced several varieties of dynamite, some of them containing mixtures of carbonaceous material with a nitrate. These were intended for work requiring a less violently shattering effect than that produced with the kieselguhr dynamite, as they contained smaller proportions of nitro-glycerine. The patent rights of Nobel, which existed until recently in this and other countries, gave rise to the production of many nitro-glycerine preparations, for which originality, and, of course, specially valuable properties, were claimed, and for which it was considered necessary to invent fancy names, in order to invest them with some feature of originality. Thus, lithofracteur was similar to Nobel's charcoal-dynamite, and the same may be said of vigorite or Vulcan powder. In some, such as dualine and petrolite, sawdust or cellulose in some form, either partially purified from resinous matters or imperfectly treated with nitric acid, constitutes the basis for absorbing the nitro-glycerine. It is a material of this kind that was found in the so-called infernal machines discovered at Liverpool, and used in the Glasgow and *Times* office outrage, and probably also at the Local Government Board, in May last. Tutonite and forcite are other recent forms of the class of dynamites which the French term *dynamites à base active, i. e.*, dynamite in which a more or less powerfully explosive preparation is used as the absorbent of a comparatively small proportion of nitro-glycerine. Inert absorbents of many kinds have been used in place of kieselguhr. Thus, during the siege of Paris, dynamite was made with alumina, sugar, precipitated silica, ash of boghead coal, etc., and one of the most efficient absorbents, and one now largely used at dynamite works in California, is magnesia alba, which retains the nitro-glycerine as effectively as kieselguhr, while the expulsion of its carbonic acid by the heat of detonation of the mixture adds a little to the volume of gas developed. The chief objection to a dynamite prepared with a vehicle of inferior absorbent power is its liability to part with its nitro-glycerine when stored in localities where the mixture is exposed to considerable alternations of temperature, when the separated liquid at once becomes a source of comparatively great danger. The employment of sodium nitrate in some of the above named varieties of dynamite *à base active* is especially objectionable, as the hygroscopic property of that salt causes the material to absorb water, which expels the nitro-glycerine from the mass.

ATLAS DYNAMITE.

One of the latest varieties of dynamite for which originality has been claimed is the so-called Atlas dynamite, in which nitrated gun-cotton is the absorbent, and which, by the incorporation of a small quantity of paraffin, has water-repellent properties. This material is practically identical with the preparation of nitro-glycerine and nitrated gun-cotton which I produced sixteen years ago, and christened glyoxilin, and with which extensive experiments were made at that time. My work in this direction affords an interesting illustration of the almost inexplicable manner in which we chemists occasionally almost touch upon and yet miss a discovery or result that after more or less protracted intervals falls to the share of a more fortunate worker. Thus my old master, Hofmann, had had methylamine, so to speak, under his hand for some time (being, as you will know, then engaged in his admirable researches on the ammonium bases) when Wurtz announced its discovery in 1849, and in speaking to me, his assistant at the time, of this, he related that Liebig had for a long time had bromine in his laboratory collection, believing it to be an iodine chloride, when Balard announced its discovery in 1829.

BLASTING GELATINE.

So, in a much humbler manner, I had been in 1867 on the verge of preparing what we cannot now but regard as one of Alfred Nobel's greatest triumphs—the remarkable explosive agent, blasting gelatine. In my experiments of 1866, being desirous of producing the most powerful mechanical combination of gun-cotton and nitro-glycerine (a dynamite in which the absorbent was itself a powerful explosive), I employed the gun-cotton which I was then making at Waltham Abbey, and which consisted mainly of trinitrocellulose, containing generally a maximum of about 8 per cent. of the lower products, more or less soluble in mixtures of alcohol and ether. I noticed occasionally, in incorporating the mixture of pulped gun-cotton and saltpeter with nitro-glycerine that the former appeared to become somewhat gummy in character, this result being due to the softening action of nitro-glycerine upon the lower celluose products existing at times in somewhat larger proportions in the gun-cotton; but this did not specially rivet my attention. Later on, Nobel, by employing a gun-cotton consisting chiefly of the nitro-products intermediate between trinitrocellulose and collodion-cotton, obtained a practically complete gelatinization of that material by its intimate blending—to an extent almost approaching chemical combination—with nitro glycerine.

Blasting gelatine, in appearance, much resembles guava jelly and contains about 73 parts by weight of nitro-glycerine and 7 parts of nitro-cotton. The nitro-glycerine is first raised to a temperature of about 50° C., and the finely divided nitro-cotton is then gradually added, the mixture being continually worked in a macerator, and the temperature maintained at a maximum of 35° C., so as to be well within the margin of safety; but the operation has to be most carefully watched throughout, that no elevation of temperature may occur approaching one which is dangerous to the stability of the nitro-compounds.

Blasting gelatine, in its most perfect form, is translucent, of a pale yellowish color, and sufficiently firm to enable a cartridge to retain its cylindrical shape if kept lying on a flat surface. It does not soil the fingers, and the components are very difficult indeed to separate, even through the agency of a solvent of both and attempted precipitation of the nitro-cotton. Of the first sample which I received from Nobel's Explosives Company I placed a portion in water, and have kept immersed for three and a half years. After a time it lost its translucency—first superficially, and gradually throughout. A very small proportion of nitro-glycerine passed into solution in the water, and the mass, at the end of three years, had increased about ten per cent. in weight. Part of the sample was removed from the water, and at once placed into the cylindrical cavity of one of the leaden proof cylinders which I use for obtaining a strict comparison of the force exerted by different explosives. It was readily detonated, and, compared with a corresponding amount of a fresh sample of gelatine, the force exerted was only

slightly inferior. A weighed portion of the sample exposed to the air very gradually regains its translucency in parting with the small amount of water which it has absorbed. Blasting gelatine varies somewhat in the readiness with which it is detonated. As a rule, it is not so sensitive as dynamite, but no difficulty is experienced in effecting its explosions with ordinary detonators, unless a considerably larger proportion than usual of nitro-cotton has been used in its manufacture. It is rendered extremely non-sensitive by incorporating with a small proportion of camphor or other solid carbo-hydrogen; and this addition was contemplated by the Austrian military officials (who have adopted the gelatine for field service purposes), in order to insure its safety from explosion by the penetration of transport wagons containing it by rifle bullets, which in its ordinary condition it is somewhat liable to, though not nearly to the same extent as dynamite. The great proneness of the camphor mixture to escape complete explosion, even when strongly confined, led to the abandonment of this idea. The chief point needing attention in the manufacture of blasting gelatine is the character of the nitro-cotton. If the latter contain an excessive quantity of collodion cotton on the one hand, or of trinitrocellulose on the other, a portion of the nitro-glycerine, or, rather, liquid mixture of that substance with a very small proportion of nitro-cotton, is liable to separate after some time, and is then not unlikely to be a source of danger.

When it is remembered that two molecules of nitro-glycerine contain an atom of oxygen above the amount needed for the complete oxidation of the carbon and hydrogen, while the small proportion of nitro cotton incorporated in the gelatine requires an additional supply of oxygen for its complete oxidation, and that the entire substance is converted into gases and vapor of water, it will be admitted, I believe, that a chemically more perfect explosive is very difficult to conceive, while in regard to its physical properties it certainly leaves very little to be desired. It is therefore not surprising that blasting gelatine should make rapid strides in the favor of mining communities, or that it should bid fair gradually to displace dynamite in many of its applications. In Austria the latter appears to have been entirely superseded by it, and it is already extensively used in many other countries, while in Great Britain a temporary check in the manufacture has already been felt a serious inconvenience. The rapid and continuous growth of the dynamite industry during the past sixteen years is demonstrated by the following statement of the annual sales from factories in different parts of the world with which Mr. Nobel is associated:

	Tons.		Tons.
1867	11	1875	3,500
1868	78	1876	4,300
1869	184	1877	5,500
1870	424	1878	6,200
1871	785	1879	7,000
1872	1,350	1880	7,500
1873	2,050	1881	8,500
1874	3,120	1882	9,500

EXPLOSIVE LIQUIDS.

A few words more, and I shall have completed this imperfect outline of the progress made in the industry and applications of explosives. One of the most interesting, original, and suggestive of comparatively recent contributions to the literature of explosives is a memoir contributed to the Chemical Society, in 1873, by Dr. Hermann Sprengel, in which he sets forth the reasoning whereby he was led, in 1871 and subsequently, to make a series of experiments which demonstrated that mixtures of strong nitric acid (specific gravity 1·5) with solid or liquid hydrocarbon, such as naphthalene, phenol, or benzol, or with other very readily oxidizable liquids, such as carbon bisulphide, may be detonated, and that potassium chlorate may be also applied in the same way in conjunction with such substances, so that cylinders of compressed chlorate might be converted at any time into explosive cartridges by saturating them with the sulphide or with a liquid hydrocarbon. He pointed out that one obstacle to the practical application of mixtures of nitric acid and hydrocarbons—namely, the heat developed upon producing the mixture, due to the nitrification which ensues (and very prone to establish violent oxidation and even ignition) may be removed by employing the nitro-products instead of the original hydrocarbons. Thus, while the addition of strong nitric acid to phenol would inflame it, the employment of trinitrophenol would actually give rise to a very considerable depression of temperature on mixing with nitric acid. And, again, the employment of nitrobenzol would be attended only by a trifling elevation of temperature, while cold would be produced by using dinitrobenzol. Sprengel urged that the facts brought forward by him were susceptible of important application, because powerful explosive cartridges or charges might at any time be rapidly prepared from two ingredients which, kept separately, are non-explosive. The suggestion to deal, in mining or military operations, with highly corrosive and more or less volatile liquids, upon the extensive scale which would be necessary if Sprengel's system were turned to practical account, has not commended itself to those experienced in such matters, but attention has quite recently been directed to the subject by a M. Eugène Turpin, who puts forward as an invention of his own what he calls a new series of explosives, which he has christened "panclastite," but which are actually Sprengel's explosive mixtures. In his memoir of 1873 Sprengel gives a table of the total percentages of oxygen, and the percentages of available oxygen, in a great number of oxidizing agents, and the superiority of monohydrate of nitric acid over the majority in the latter respect is there shown. Turpin uses, or says he uses, anhydrous nitrogenperoxide as the oxidizing agent in his panclastite series, together with carbon-bisulphide, or nitro products of hydrocarbons. He therefore carries out Sprengel's suggestions, selecting for the purpose an oxidizing agent of comparatively costly and inconvenient nature, and certainly not superior in oxidizing power to the strongest commercial nitric acid.

FIRING OF EXPLOSIVE SHELLS.

A more legitimate use has been recently made of Sprengel's results by Herr Gruson, the well-known iron-plate and projectile manufacturer of Magdeburg. It has long been much desired to increase the destructive as well as the penetrative power of shells, and very many attempts have been made to apply what are characterized as violent explosives as charges for shells; but the liability of even the less sensitive of these to ignition by friction or concussion has rendered the problem a very difficult one. The first shock imparted to a shell on firing a gun causes the body of the former to move forward before motion is translated to its contents. Hence the particles composing the charge become compressed toward the rear end or base of the shell, with a force which in the case of gunpowder is sufficient to convert the grains into one compact mass. They are consequently submitted to violent friction throughout the mass of the charge, whereby the ignition of a readily explosive body is very likely to be determined, the shell being thus exploded in the bore of the gun, and the bursting, or at any rate great injury, of the latter is the inevitable result. The friction of portions of the charge against the inner surfaces of the shell is also attendant upon the first forward motion of the latter, and the great liability of this to ignite some gunpowder has necessitated the lining of our shells with lacquer, and even the employment of bags or shell-linings over the lacquer, to contain the powder-charge and protect it from the risk of premature explosion. In the earlier of our experiments with gun-cotton, trials were made of shells charged with this material in the form of a plait (like an Argand lamp wick), the particular form devised by Von Lenck for the purpose of attaining the most rapid explosion in a shell, but although those were fired from mortars with very small powder-charges, they almost invariably exploded prematurely. Afterward shells with removable bases, to admit of their being filled with accurately-fitting cylinders of highly compressed gun cotton, there being just room for a bag lining between the charge and the sides of the shell, were fired from the 7-inch Armstrong gun; but the second or third shell exploded prematurely, bursting the wrought-iron gun and scattering the fragments to great distances. Successful results were subsequently obtained with a powder composed of saltpeter and ammonium picrate, which, under the name of picric powder, I devised thirteen years ago, for use in shells (it being prepared in France contemporaneously by M. Boutiny). This powder proved to be even somewhat less sensitive than ordinary gunpowder, and there was a tendency to some portion of the charge escaping ignition when the shell burst. The satisfactory results obtained shortly afterward with shells charged with wet gun-cotton led to the abandonment of experiments with picric powder, which is, however, about to be taken up abroad.

The employment of wet gun-cotton, and, indeed, of any other violent explosive agent, in shells, necessitates the fitting of the latter with a fuse provided with a proper exploding or detonating arrangement. The construction of a fuse which should be effective when the shell struck or penetrated the structure fired against, and which at the same time should be entirely free from liability to premature action of the gun, was a problem by no means easily solved, but was eventually accomplished. Yet there still remains a possibility of the premature and disastrous bursting of a shell loaded with a powerful explosive agent, due to accidental weakness of, or defect in, the body of the shell itself; and although this source of danger is very remote in the present day, it cannot be absolutely guarded against. Hence, the idea of Mr. Gruson to adopt Sprengel's mode of quickly producing violent explosive mixtures to the charging of shells in such a way that they shall be absolutely safe so long as they are in the gun, and be explosive almost directly after they have been projected, presents features of much interest, and probable importance. One mode in which this idea has been carried into execution, and successfully, so far as a few experiments warrant that conclusion, is as follows: The fore part of the shell contains a sealed glass vessel, well protected and filled with strong nitric acid; the rear part is filled with the solid dinitrobenzol. In this condition the charge in the shell is quite harmless; but when the gun is fired, a simple mechanism breaks the reservoir of acid, and the latter is driven back on the first motion of the shell into the dinitrobenzol, forming a mixture which the rotation of the shell completes almost immediately, but not until the shell has left the gun. The shell is then explosive, and in a condition to produce powerful destructive effects as soon as a time or concussion fuse comes into action, in the usual manner. It is evident that the arrangement of the components of the explosive charge may be modified to suit different requirements, and there appears no reason why such arrangements should not be made quite efficient for service purposes. Such a shell may perhaps not be equal in destructive power to charges of the most powerful explosive agents with which we are now acquainted, but if, as appears most likely, it insures the safety of the gun, and of the men who are working it, while at the same time it is very greatly superior in power to a shell charged with powder, Mr. Gruson's adaptation of the results of Dr. Sprengel's investigations will afford an interesting and important demonstration of the fact, which has been abundantly illustrated in connection with many branches of chemical industry, that the results of scientific research, however deficient in practical value they may at first sight appear, may at any moment acquire prominence and practical importance, as leading to the ready solution of long fought but hitherto unconquered difficulties.

SHEET METAL STATUARY.

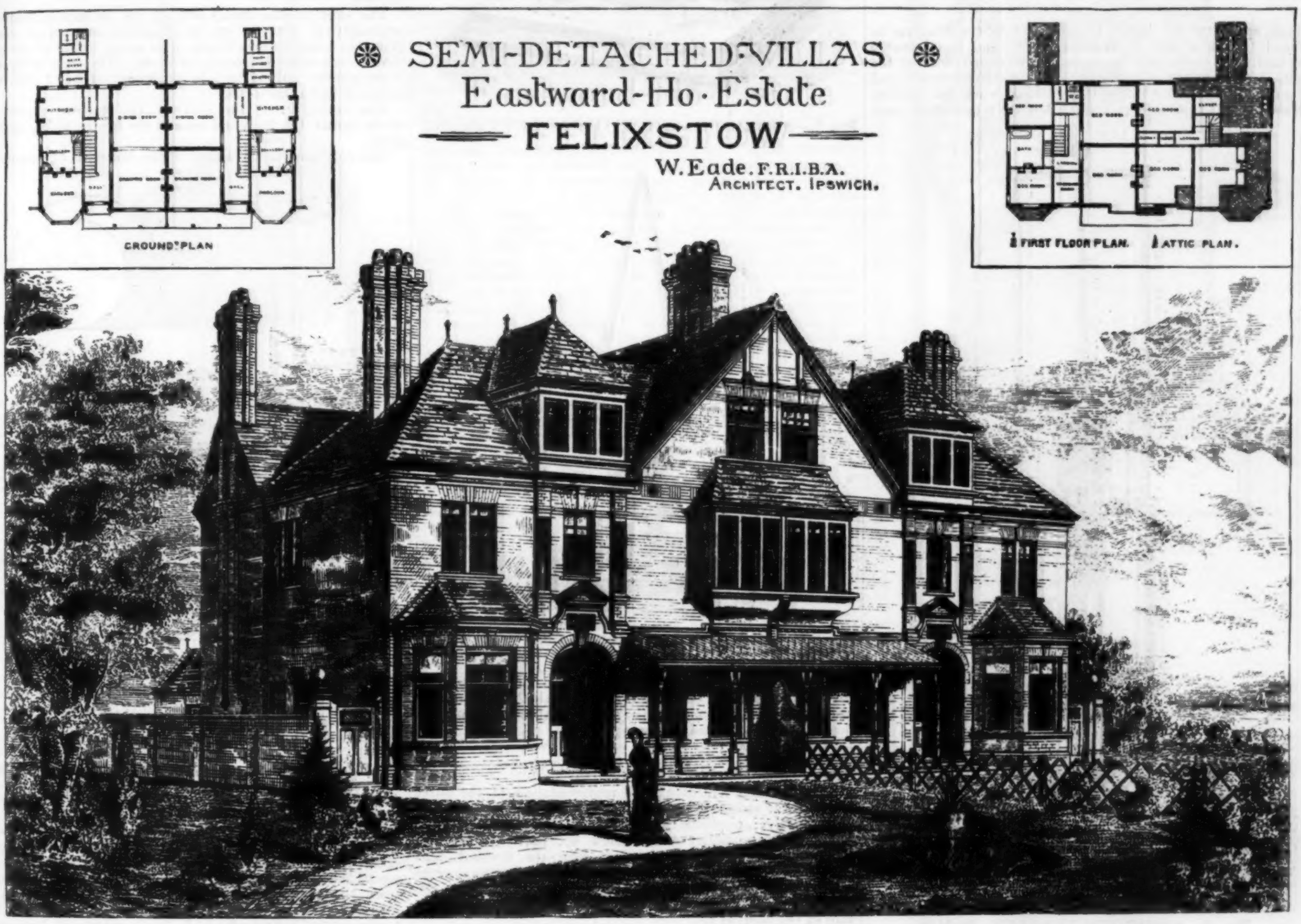
AMONG the interesting exhibits at the Louisville Exposition, now in progress, is a group of sheet metal statuary designed for the new court-house being built in New Philadelphia, Ohio, and which forms a part of the exhibit of Messrs. Bakewell & Mullins, of Salem, Ohio. The group is an allegorical representation of Law, Justice, and Mercy, and is intended to surmount the dome of the building mentioned, at a height of 175 feet from the ground.

GROUP IN SHEET METAL.—COURT HOUSE, NEW PHILADELPHIA, OHIO.

At different times, says *The Metal Worker*, various newspaper comments have been made upon sheet metal statuary, for the most part in a spirit of ridicule. So far has this gone in some cases that "Galvanized Justice" has become almost proverbial. The utility of sheet metal work of this kind, provided always that it is well designed and properly constructed, can hardly be gainsaid. The immense weight of figures carved in stone or cast in zinc or other metals, without reference to their great cost, is enough to prevent their use in many places where groups or single figures would be desirable. The Salem concern, in the hands of its present proprietors, as also under the management of former owners, has, perhaps, given quite as much attention to the production of art work as any establishment in the country. The usual plan which has obtained in the manufacture of work of this kind had been that of individual discretion and judgment upon the part of some workman who was skillful with his hammer. In other words, instead of an artist being employed to model the figure, both modeling and construction were done at one time by a workman seldom possessing anything more than a fair mechanical skill. Many examples of work

constructed in this manner are familiar to our readers, and might be cited in this connection. The Salem concern, however, has pursued a different plan. According to the nature of the work required, the very best artistic talent has been employed; first for modeling the group either full size or to some definite scale; then for the preparation of dies of such parts as could be advantageously struck up in a press; and lastly, in the arrangement and management of the drapery, leaving the individual workman nothing more to do than to prepare and join the several parts of which the figure is composed. In the present instance the heads, arms, faces, hands, feet, and some portions of the trimming of the drapery were made in dies, thus giving every advantage of the fine lines which would be imparted to a group at the hands of a modeler or sculptor. A substantial framework sufficient to hold the parts together and resist the effects of the wind was employed as a skeleton about which the figures were constructed. The drapery, made in pieces, has been skillfully applied, until, when viewed by the visitor to the exposition above mentioned, the whole presents a harmonious appearance and at first glance would lead one to think it was of cast metal or sculptured stone. The entire weight of the group as shown in our engraving is about 1000 pounds. The total height is 14 feet.

The artistic conception of the group is one entirely appropriate for a court-house. Law, with an attentive, impartial bearing, sits upon a firm basis of rock, holding the tablet, on which, with pointed pencil, she inscribes the edicts of authority. Justice, sitting by her side with countenance stern and eyes blindfolded, holds the scales in one hand and the sword in the other, ready to execute the mandates of Law; while Mercy, standing between, looks down upon Justice and Law with a pleading, interceding expression, and is about to place a hand gently upon the head of each. This group is by far the most ambitious piece of sheet metal work that has been attempted in this country. It suggests possibilities which this construction presents as a means of architectural embellishment. The folds of the loose, flowing, conventional gowns in which the figures are clad have been faithfully rendered by the workmen, while the expression of the faces and all the various proportions of the group are as clear-cut and exactly defined as if the statue were a casting in bronze.



SEMI-DETACHED HOUSES, EASTWARD HO! ESTATE, FELIXSTOWE.

These houses have been erected on an estate laid out for Messrs. Bugg & Jolly, from plans prepared by Mr. W. Eade, F.R.I.B.A., Ipswich.

The houses stand in an attractive position on the cliffs, and have a fine sea view, commanding the entire sweep of Felixstowe Bay. They are substantially and carefully built of best red Suffolk bricks. The roofs are covered with Broseley plain tiles, and the fittings throughout are of good character. Mr. Thos. Ward, of Felixstowe, was the contractor for the works.—*The Architect.*

A Very Costly Book.—Not long ago a book was sold in London for $9,750. This is said to be the highest price paid for a single volume during the last ten years. The book was a copy of Petrarch's songs, and was printed in Venice in the year 1470. It is very rare, and there is not a single copy of that edition of the work in all America.

WHAT TO DO WITH THE WIRES.

To the Editor of the Scientific American:

The great and pressing question, what to do with the electric wires in our city streets, is one which cannot be hastily disposed of. On the one hand, their constant multiplication is becoming under present arrangements a serious inconvenience; on the other, the wires are an essential part of our business and social machinery, and to dispense with them or to impair their efficiency would be worse than the evils we now complain of. The demand which is now so rife that they should all be put immediately under ground, is an illustration of the inconsiderate way in which a popular cry is taken up and echoed regardless of the problems involved, or the consequences that would inevitably follow. In the first place, burying the wires would probably cause to the public a very imperfect and expensive service. It is even doubtful whether the telephone could be worked at all as a practical apparatus. And in the second place, the inconvenience that would result from the constant obstruction of the sidewalks and roadways for additions, alterations, or repairs of the plant would become at once an intolerable nuisance. The object of this communication is to suggest a plan which is simple, practical, and permanent, and which offers advantages not pertaining to any other system which has been proposed.

Let us remark at the outset that one of the chief objections to the present unsightly system of pole supports is their unnecessary number. Every company has its own separate lines, and in consequence our streets are crowded with groups of poles, when a single line of supports would often be quite sufficient for all the wires. These poles not only obstruct travel, but they are unsightly and often dangerous, and in case of fire their network of wires close to the burning building impedes the firemen and causes loss of property and often of life. The remedy we propose for these evils consists in *the erection by municipal authority of a single system of supports, and requiring all electric companies to use it, and pay to the city government a suitable rental therefor.*

The supports that we would suggest under such a system should be light wrought iron posts, from 50 to 100 feet in height, and from 200 to 400 feet apart. These posts should be set in pairs, one post on each side of the street, connected by horizontal ties crossing the street at different elevations. Upon these ties the wires would rest, keeping as much as possible in the middle of the street. Of course the different companies would have their respective stories or altitudes, and the poles could be extended upward as far as might be necessary to accommodate them all. The wires need not rest directly on the transverse ties, but on sliding saddles, so that in case of fire the whole body of wires could be drawn to the opposite side of the street. To furnish intermediate support for the wires as well as stability to the system of posts, one or more iron rods of an inch or two in diameter may pass from post to post along the street, high above the sidewalks. Upon these longitudinal rods, cross bars may rest at intervals, or may be suspended from them, supporting the wires where necessary, and available as a means of hanging electric lights and for other purposes.

The uprights may be utilized for various purposes, such as gas posts, awning posts, and for postal and fire alarm boxes, etc., etc. They should also be so erected as to serve as lightning protectors. In case of fire the horizontal rods could be made useful to support hose and ladders, and to facilitate the escape of persons in the burning building. Access to the wires for repair or renewal would be easy and without inconvenience to the public, and by a judicious distribution of the wires through different streets there need be no crowding of them in any. There would, moreover, be abundant room for future multiplication of them to any extent.

We may add in closing that this system of municipal ownership and control over the highways of electricity is the natural and appropriate solution of the questions connected with the use of our streets by the electric corporations. The usurpation of this use by the latter has grown up gradually and has been tolerated in consideration of the conveniences which they have furnished to the public. But as it is now apparent that these highways of wire are to be a permanent and a growing feature in our cities, it is proper and necessary that municipal governments should adopt some permanent and comprehensive plan with reference to their management and control. It is believed that no underground arrangement can ever be made practicable. Apart from the electrical difficulties, its great expense and inconvenience as well as its want of adaptability to an indefinite future growth would prevent its adoption. The plan we have suggested seems to meet all the requirements of the case, and to furnish a method which would be mutually advantageous to the municipalities and to the electric corporations. The one would exchange the present unsightly and cumbersome chaos of poles for an orderly and convenient system under governmental regulations, and would derive an annual revenue therefrom; the other would be relieved from the expense of maintaining so many separate lines of support, and of the legal controversies and clashings of rival interests arising therefrom.

H. T. Blake.

New Haven, Ct., Sept. 24, 1883.

MELTING METALS BY ELECTRICITY.

The electric furnace possesses two great advantages—the temperature which can be produced is only limited by the refractory resistance of the crucible, and the heat is developed in the materials which are to be melted, without first traversing the recipient. Six pounds of forged iron were submitted for twenty minutes to the action of the arc, and the metal was then poured into a mould. It was found to be crystalline and could not be forged. This difficulty may be remedied by adding a little manganese before pouring out; but the reason of this action is not understood. Three quarters of a pound of copper were melted in charcoal dust for an hour, at the end of which time all but three-quarters of an ounce had been vaporized. The persons who were present did not perceive any disagreeable effects from the atmosphere, which they were obliged to breathe. Eight pounds of platinum were entirely melted in about a quarter of an hour. A half pound of powdered tungsten was submitted to the action of the electric arc, in a clay crucible. Very dense fumes escaped, and a cavity about a half an inch deep formed at the summit. The metal appeared to have been melted to only a very slight depth below the cavity. The unmelted portion was covered with very beautiful crystals, which when examined by a microscope were found to be prismatic, but they were not very uniform. The crystals were evidently formed by the slow cooling of the distilled vapor. Experiments were tried with various other metals, showing that the quantity of any given metal which can be completely melted in an electric furnace, and the time requir-

ed for the fusion, depend upon the interval between the point of fusion and the point of vaporizing, as well as upon the thermal conductibility of the metal. Thus it happens that platinum is melted much more easily than steel, and in a much greater quantity, for the same expenditure of energy.—*L'Electricien.*

SCHMIDT'S ELECTRIC LAMP.

AMONG the arc lamps shown at the recent International Exhibition of Electricity, at Munich, was a full series of Mr. Franz Schmidt's regulators. The principle upon which

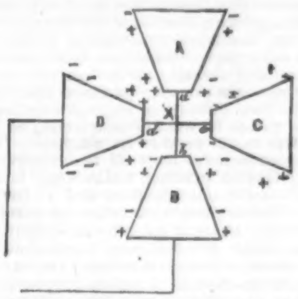


FIG. 1.—PRINCIPLE OF SCHMIDT'S ELECTRIC LAMP.

these apparatus are based is explained by the diagram in Fig. 1. Each of the electros, A, B, C, and D, is doubly wound with coarse and fine wire. The coarse wire of the four electros forms, with the arc, the principal circuit, and the direction of the winding is such that, when the current passes, B and D as well as A and C tend to recede from each

FIG. 2.—SCHMIDT'S ELECTRIC LAMP.

other. The fine wire, in derivation on the arc, forms a circuit wound in such a way that, under the influence of the current that is traversing it, B and D as well as A and C tend, on the contrary, to approach one another. When the lamp is in operation, these two actions counterbalance each other so as to keep the carbons at a normal distance apart. When the arc becomes too large, the juxtapositing current increases and the carbons are brought back to their first position.

Figs. 3 and 6 show two applications of this principle with 4 and 2 electros. In the apparatus in Fig. 4 the two electros, B B', that attract and repel each other are mounted upon rails, R, and are guided by a rod, T. In the arc in Fig. 5, the motions of the electros are transmitted to the carbons by a double system of racks. Finally, in the lamp shown in

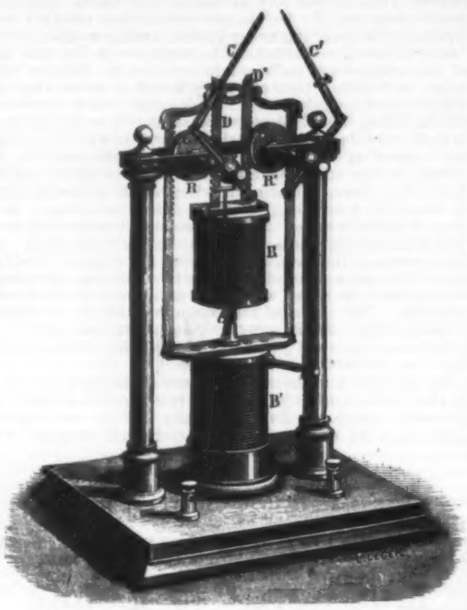


FIG. 5.—SCHMIDT'S LAMP WITH RACK MOVEMENT.

FIG. 6.—SCHMIDT'S LAMP WITH TWO ELECTROS.

Fig. 2, the action exerted between A and B is combined with that that takes place between B and C. All these apparatus are evidently ingenious, but they possess absolutely no practical value.—*La Lumière Electrique.*

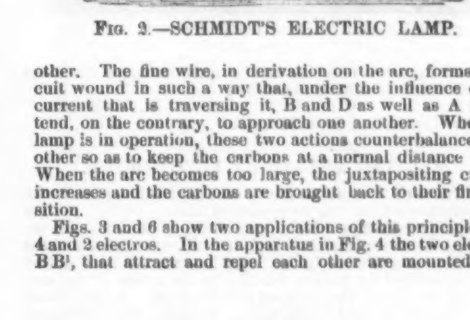


FIG. 3.—SCHMIDT'S LAMP WITH FOUR ELECTROS.

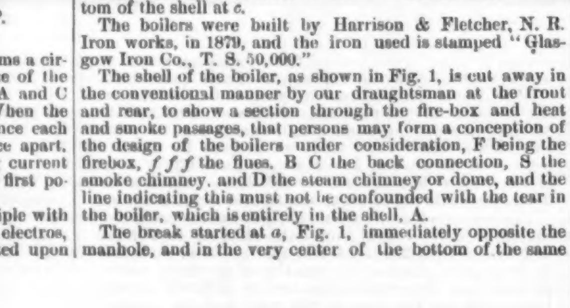


FIG. 4.—SCHMIDT'S LAMP WITH CARRIAGE MOVEMENT.

THE RIVERDALE'S BOILERS.

THE diagrams will give a fair representation of the burst boiler of the steamer Riverdale, which lately blew up in the Hudson River, opposite this city.

Fig. 1 is the boiler which blew up, partly in section; Fig. 2, a section across the shell near the manhole and through the torn course; and Fig. 3, an exaggerated cross section of the shell at any point of its length, showing the condition of the iron from erosion or corrosion at the bottom of the shell at *c*.

The boilers were built by Harrison & Fletcher, N. R. Iron works, in 1879, and the iron used is stamped "Glasgow Iron Co., T. S. 50,000."

The shell of the boiler, as shown in Fig. 1, is cut away in the conventional manner by our draughtsman at the front and rear, to show a section through the fire-box and heat and smoke passages, that persons may form a conception of the design of the boilers under consideration, F being the firebox, *f f f* the flues, B C the back connection, S the smoke chimney, and D the steam chimney or dome, and the line indicating this must not be confounded with the tear in the boiler, which is entirely in the shell, A.

The break started at *a*, Fig. 1, immediately opposite the manhole, and in the very center of the bottom of the same course. The direction of the tear was in the direction of the arrow, and remained within the same sheet until it reached the longitudinal seam, when it passed into the neighboring courses, as shown, thence around the boiler one and one-quarter times, as represented by the rents and dotted irregular lines.

Fig. 2, which shows the position in which the boiler lay on the dock, is a section through A, Fig. 1, and shows both lips of the primary rupture, *a a*, and the position the torn shell assumes when in repose.

At *c*, Fig. 3, the shell is eaten regularly its whole length, so that not more than one-third of the original thickness remains as an average; but there are places which are not one thirty-second of an inch in thickness, and notably at *a*, which may be said to be entirely eaten through, as the edges show no thickness that can be appreciated. On the line, *c*, throughout the length of the shell, the heads of the rivets, for an average width of four rivets, have, in most cases, entirely disappeared, and the heads of the bolts in the soft patches, which must have been applied within a comparatively recent time, are also eaten.

At all the positions marked *b* on the line, *c*, the seams were "soft patched," and at the position, *b'*, within one foot of the handhole, a bolt had been passed through a hole with a big washer for a patch.

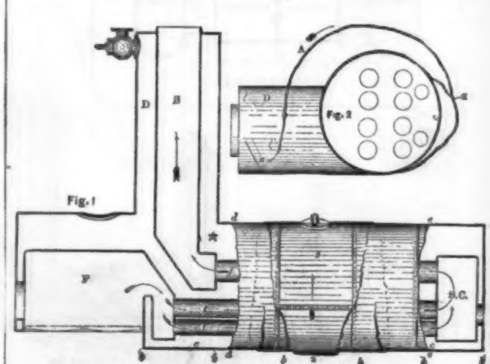
At the position marked with a "star," six of the braces which joined the smoke connection with the shell of the boiler were broken, and to all appearances were broken previous to the time of the disaster, as the fractures are covered with deposit.

On the boiler which did not blow up were counted seven "soft-patches" along the bottom of the shell and in the fire-box.

The shell of the boiler was $\frac{7}{32}$ of an inch in thickness originally, as near as can be measured with a rule, and is probably nearer to No. 3 Am. wire gauge (0·229 of an inch) than to any other standard thickness. The rear head sheet is apparently full $\frac{1}{4}$ inch in thickness, or No. 2 Am. wire gauge (0·257 of an inch).

The condition of the iron of the boilers, except the shells under the flues and around the bridge walls, appears good.

The condition of the seams of the boiler at C, requires a



ILLUSTRATIONS TAKEN FROM THE BURST BOILER OF THE STEAMER RIVERDALE.

thorough investigation at the hands of engineers as to its cause and the means of prevention. To the ordinary observer it is corrosion; but why, if corrosion in the ordinary sense, should the heads of the rivets be as cleanly removed from the shell, at all the seams, unless the seams in the flanges of the heads, as if they had been removed with a "side-cutter"? And why is it for a width of four rivets only, leaving the very next rivet almost intact, and the next as good as the day it was driven?

Evidently it is the work of internal circulation, which carries particles of scale, etc., along the bottom with an action similar to the sand blast. The gravity of the particles tends to keep them on the bottom, and the returning current of the water which has been forced upward between the flues by the heat must be strongest along the meridian at C, where it must have a tenfold ratio of velocity to any other part of the boiler. The action of pure water alone will erode iron, but when assisted with floating particles its action must be many times increased.

The above facts exhibit a deplorably culpable case of dereliction of duty on the part of the owners of this vessel. The engineer must have been aware of the condition of the boilers, and especially of the one that blew up.

Within one foot of the rear handhole, right in the center of the grooving, a leak had started, because of the thinness of the iron. To repair it the rear handhole plate had to be removed and the boiler emptied; then the hole or crack was rounded with a drift pin to admit a bolt. Then a bolt was passed through with a large washer on both sides of the plate, with lampwick or hemp and paint to stop the leaking.

If this were the only patch, and it were beyond the reach of the hand, there might be some plausibility for the plea of ignorance; but in this case there can be none. Every seam on the bottom of the boiler was patched with poultices of "putty" held on with thin sheet iron, and bolts passed through the shell. The other boiler was in the same condition, with not less than seven such "soft patches."

The revocation of such an engineer's license for all time is a thing that should be assured, even if he did not know the condition of his boilers; but if it is proved that he did, he should be sent to State prison.

If the owners of the boat also knew the condition of the boilers, not from personal knowledge, but on information,

or failed to learn through neglect to make inspection, they are also equally guilty, and should be made to feel the enormity of their acts, pecuniarily or otherwise.

Had the annual inspection been thorough, it could not have failed to discover the state of affairs; but evidently it was not, as the condition of the bolts which hold the manhole plate in the entrance to the back connection (of the boiler which did not blow up) show that the nuts have not been removed from them in a long time. But to any one conversant with the methods of the average inspector, this is nothing to be surprised at. "Asking the engineer if the boiler is in good condition, putting his head in the manhole, telling them to fill up, and applying the pressure"—such are his methods. Then, unless something positively blows out, the certificate is almost always sure to follow.

We are satisfied that too often a disposition of the owners to "finish the season without lying up" induces them to risk boilers of like character every summer. In fact, we know that if the inspection were as rigorous as it should be, one-third of them would be condemned.—*Sanitary Engineer.*

IMPROVED DRILLING MACHINE.

THE increasing demand for high-class boilers capable of withstanding the high pressure now generally adopted has

BORLAND'S DRILLING MACHINE.

necessitated the use of machinery for drilling the rivet holes in boiler shells. To insure accuracy, the holes should of course be drilled after the shell has been bent into the cylindrical form. To effect this, Mr. Borland has devised a very useful machine, which we found on the stand of Messrs. Holden & Brooke, of St. Simon Street, Salford, Manchester, at the late Engineering Exhibition. The drill, which we illustrate, is designed to work inside a boiler shell, and to drill two holes diametrically opposite, at the same time. The two spindles (which are in line) rotate in opposite directions, and thus obviate the necessity of having drills ground right and left hand. The power is transmitted noiselessly and smoothly by means of a 1-inch cotton rope, no gearing whatever being employed with the exception of a worm wheel to give the automatic feed; the drills can also be fed and withdrawn by hand as required. The machine can be started and stopped instantaneously without arresting the motion of the driving rope, and the whole drill can be raised, lowered, or swiveled by one man, without the use of a crane.—*Iron.*

GAUCHOT'S AUTOMATIC REGULATORS AND PUMPS.

FOR a long time past endeavors have been made to secure a constant level in boilers, not only because of the security that would result therefrom, but also because of the saving in fuel that it would effect. After a prolonged examination of the subject, Mr. Paul Gauchot, of Paris, reached the conclusion that an apparatus to effect this end should combine within itself the following conditions, viz.:

1. The cut-off should neither become rusty nor scaly.
2. The float, in order that it may preserve all its mobility, should act, without exerting any power, upon the cut off, and the latter should operate without the concurrence of the former; these two conditions united assuring of the working of the apparatus.
3. The feed should be intermittent, so as to prevent scale from depositing in the pipes at the entrance to the boiler.
4. Whatever be the boiler's delivery, the same small quantity of water introduced after the level is reached should cause the feed to cease; and, when such quantity of water is consumed, the feed should begin again; this condition leading to a constancy in the level.
5. The float should be arranged in a vessel external to the boiler and at any level whatever above the water, so as to avoid any difficulty in its installation.
6. The operations of the apparatus should be perceptible to the eye and ear.
7. The operation of the apparatus should be capable of being arrested in cases where it became necessary to raise the level of the water in the boiler.
8. Finally, the apparatus should be strong, and free from parts that might wear out through use, as much for the sake of having it operate surely as to avoid those repairs that would be necessitated through momentary stoppages in the running of the apparatus.

All the above named conditions are fulfilled in Mr. Gauchot's feed regulator (shown in Fig. 1), an apparatus designed to be arranged above, in front of, or at the side of a boiler, and connected with the latter by a pipe placed as vertically as possible, and entering the generator as far as to the water level that it is desired to obtain. When the water in the boiler rises above the normal level, the pipe leading to the chamber, A, dips into the water, and the latter cuts off communication between the steam in the boiler and that confined within the said chamber. The steam then becomes cool and condenses, the chamber, A, fills with water, and the float, B, rises. When, through consumption of water, the level descends below the extremity of the pipe, the water in the chamber flows out, and the float falls. In the first case, the float stops the motion of the clack, D, by means of an eccentric, and causes the feed to cease. In the second case, the operation of the clack, D, is free, and the feed goes on.

On opening the cock, R, the water from the pump can flow directly to the boiler without passing through the valve, D, thus permitting of raising the level of the water as high as may be necessary. It will be seen that, with this regulator, the feed pump does not cease to operate. The result of this is that when the introduction of water into the boiler is shut off by the apparatus, the water furnished by the pump must return to the well through a return valve.

When the generators are not of great power, the work lost by the passage of water through the safety valve is not of sufficient importance to pay any attention to; but, in important installations, this system, as a consequence of the necessity of furnishing a quantity of water that has to suffice for the maximum power of the engine, and at a pressure greater than that that can exist, even accidentally, is accompanied by a waste of power that is four or five times greater than is strictly necessary. Now, as the introduction of water into the boiler consumes about one per cent. there evidently results a loss of 4 to 5 per cent. in coal. The stoker can, it is true, remedy this matter by regulating the suction cock in such a way as to limit the excess of the pump's delivery, while at the same time making sure that it delivers a sufficient amount; but, if the apparatus for regulating the water level could act upon the pump so as to throw it into gear when the level lowers, and to throw it out of gear when the proper level is reached, the expenditure of power necessary to effect the feed would be reduced to a minimum, and its security assured of. Now, this a result that is obtained by Mr. Gauchot's automatic pump, shown in Fig. 2—an apparatus which, among its other advantages, possesses the further one that it acts as a meter for measuring the quantity of water introduced into the boiler. Even the number of piston strokes may be registered, as is already done with the pressure. By these means the manufacturer will be enabled to ascertain the quality of his fuel; he will know the power consumed by his motor, accessory machines, and shafting; he will be able to assure himself whether or not these latter are in a good state of repair; he will be able to ascertain the state of his boiler and its relative delivery, and he will even be enabled to know the hour at which his various machines were set running and stopped.—*Chronique Industrielle.*

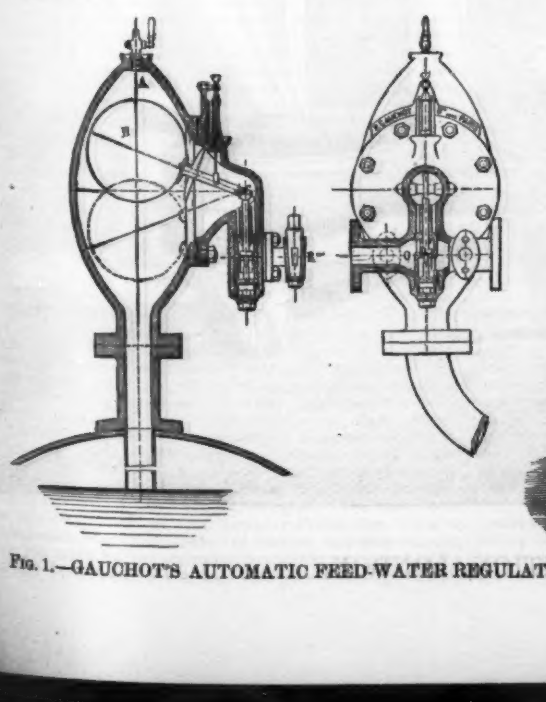
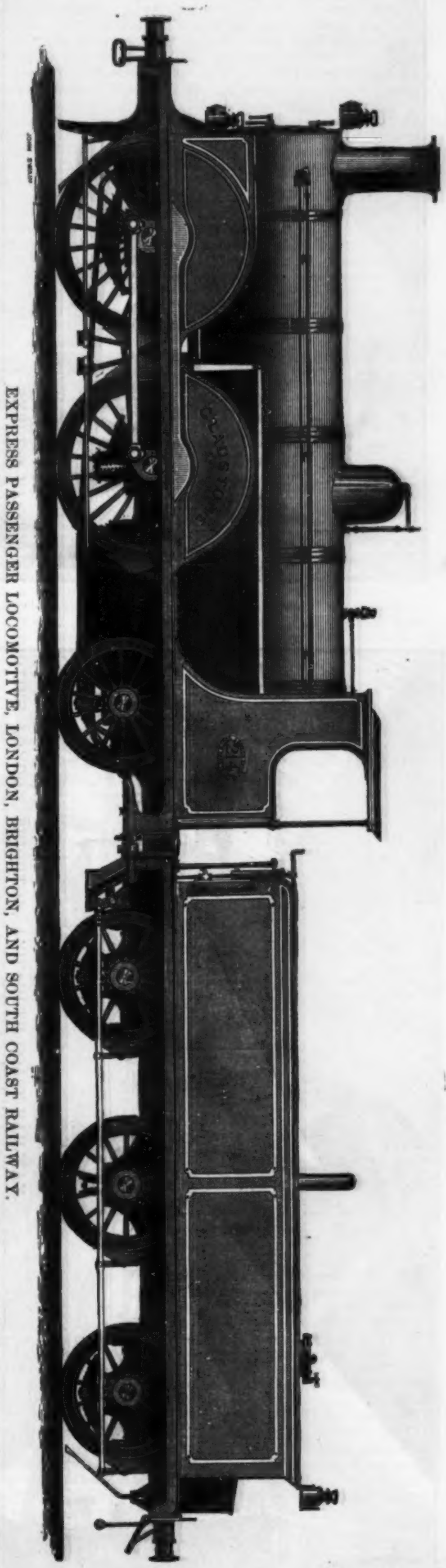


FIG. 1.—GAUCHOT'S AUTOMATIC FEED-WATER REGULATOR.

FIG. 2.—GAUCHOT'S AUTOMATIC PUMP.

NEW LOCOMOTIVE.

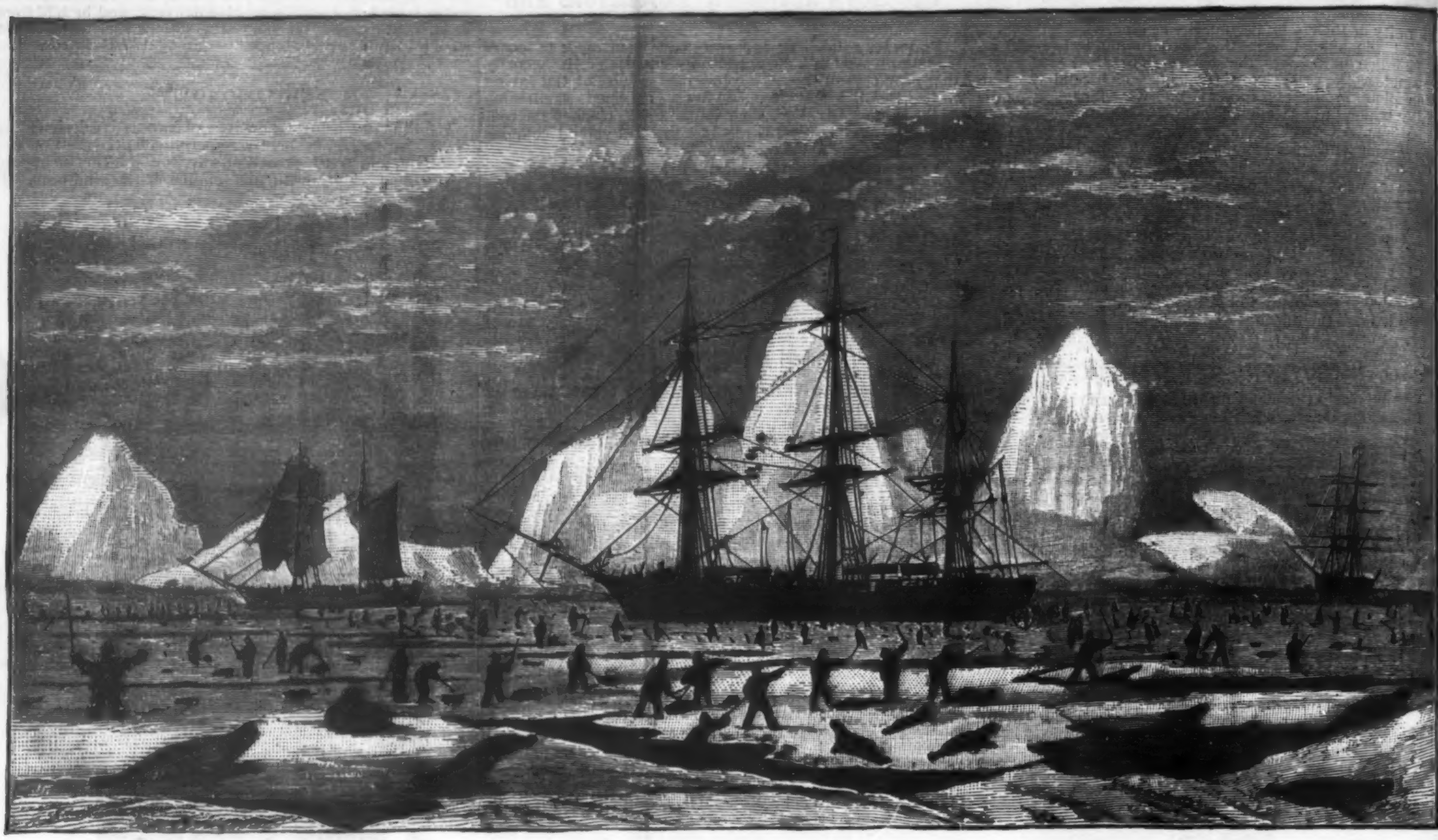
WE illustrate below a new type of locomotive designed by Mr. W. Stroudley, locomotive superintendent of the London, Brighton, and South Coast Railway, for working heavy express trains. This is the first engine of the kind built. It



EXPRESS PASSENGER LOCOMOTIVE, LONDON, BRIGHTON, AND SOUTH COAST RAILWAY.

has many peculiar features, and its performance during the six months which it has been at work has been eminently satisfactory. It has cylinders 18¼ in. diameter by 26 in. stroke, with the valve chests underneath the cylinders, and is, so far as we know, the most powerful engine for its weight, 38 tons, in existence. It has been carefully indicated, and has exerted over 1000 horse power at fifty miles an hour. Many of the results obtained are curious and interesting. It will be seen that Mr. Stroudley does not hold the opinion that small leading wheels are essential.—*The Engineer.*

WHEN tinned iron, says P. Carles, serves for containing alimentary matters, it is essential it should have no lead in the tin. The lead is rapidly oxidized in the neutral acids of the contents of the vessel.



SEAL HUNTING.

BOATS AND NETS.

THE INTERNATIONAL FISHERIES EXHIBITION, LONDON.

NEWFOUNDLAND SEAL-HUNTING.

In the varied and extensive display of marine industries all over the world, shown at the International Fisheries Exhibition, London, no section is more deserving of consideration than that of Newfoundland, historically the earliest, and geographically the nearest British colony. Although the French, as well as the English, have for centuries been active on the Newfoundland fishing grounds, they are still as productive as ever, and seem to be inexhaustible. Cod, herrings, mackerel, salmon, and lobsters abound. Of codfish alone the exports average over 1,500,000 cwt. annually, and in 1882 the official valuation amounted to £1,646,118. The seal-hunting, which is also an occupation of great value, was formerly carried on by sailing vessels; but twenty-four large steamers are now employed, and these often make two sealing voyages in the season, which continues from March 10 to May 10, during which period the ice floes are drifting about upon which the adult seals have come to whelp. After the sealing season these steamers are employed in the cargo trade, carrying goods and merchandise to various countries. The average capture of seals is from 300,000 to 400,000, but as many as 700,000 have been taken in a single season. This department of the exhibition at South Kensington is one of great interest, in its zoological as well as in its commercial aspects. The stuffed seals, the models of sealing ships and steamers, showing the modes of capturing the animals on the fields of floating ice, the fine trophy of seals' skins and seal leather have special attractive features for the popular mind. On the pinnacles of an iceberg are to be seen the adult animals with their progeny. This is the starting point. There are, next, a few very fine furs, with white or black hair, of excellent quality, such as ladies prize for their capes and cloaks. But it is not to the advantage of the Newfoundlander to furnish these to the market. There is more profit to be made by allowing the seals to attain fuller maturity. The young seal loses its white fur in three weeks, and the killing of the young animals under this age is prohibited. It is the adult skin and the fat which have the highest commercial value; and it is forbidden to bring in the produce if the skin and fat are under 30 lb. in weight. When the young seals are eight or ten days old, the pelt will weigh only from 12 lb. to 14 lb.; but growth increases at the rate of 3 lb. a day, so that at the end of twenty-five days the pelt will have attained to from 40 lb. to 45 lb. The young seals are thus in their best condition at the beginning of April, or at the time when they take to the water. The animals when killed on the ice are cut open, and the skin, with its layer of fat, is stripped off, the fat being next separated from the skin by the knife. This fat is cut up and put into steam vats and the oil steamed out. The skins are salted in bulk, and when cured are shipped to England. The whole of them come to England, and are here made into leather. The skins are thick enough to be split into two and often into three layers. The tanning and production of the leather is done entirely in this country, nearly all our patent leather, and certainly the best of it, being produced from the Newfoundland seal skins. Even the excellent specimens in the trophy itself in this section are English-made leather. Among the rows of tall glass-stoppered bottles in the exhibit may be seen samples of seal oil of wonderful purity and transparency, all but colorless, and almost without smell.

Only sailing-vessels were formerly employed in the sealing voyages, but out of nearly 400 such vessels, varying from a hundred to a hundred and fifty tons burden, and generally of brig or brigantine rig, there are not twenty now remaining in this service. These were built very strong, to resist the pressure of the ice surrounding them when at their work, being full-timbered, sheathed and with bold beams passed through the vessel, the bows being secured with iron. They were not, however, so strong as the present steamers, which are from 300 to 600 tons, and of from 80 to 150 horse-power. These have from six to eight feet solid deadwood in the bows, and thick sides double planked, the outer planking being either of "green heart" or "ironwood." They carry on their expeditions from 200 to 300 men each, and on the 10,000 hands employed in this hazardous occupation of seal capturing the Newfoundlanders pride themselves, as a body of men that are not to be matched for bodily strength, daring, and endurance. There is said to be not a man of their number over thirty-five years of age; and the Dundee vessels always get their sealing crews from the island, as their own men, when the noted Scotch port first entered on the fishery, could do nothing as compared to the Newfoundlanders. The breaking away of the ice, the cold, and many incidents peculiar to the ice-fields are calculated to give rise to considerable risk of life. It will be remembered that, in June last, fifteen sailing schooners, fitted out from the Magdalen Islands, were firmly jammed in an ice-field north of the Straits of Belle Isle, when the crews were for some days in great peril, and in a starving condition; but assistance was sent from Newfoundland, and they were all happily rescued.

One of our illustrations is a view of the western part (north side) of the long and lofty gallery devoted to the British sea fisheries, and to a variety of British-built boats, including some used for fresh-water fishing, immediately adjacent to the Entrance Hall. It contains, on the right hand, a few of the river-boats of Messrs. E. Searle and Sons, Lambeth, and the Meiter and Berthon collapsible dinghies, canoes, and punts, which can be folded up in a small space; while to the left hand are shown first-class sea-fishing boats, from the east coast; beautiful models, chiefly of American fishing-vessels, on the tables; and a large collection of nets used in the British mackerel, pilchard, herring, sprat, and other sea-fisheries, by Mr. Craggs, of Lowestoft, and other manufacturers, besides crab and lobster traps, fishing-lines, and many articles of the piscatorial craft.—*Illustrated London News.*

[Correspondence of the Public Ledger.]

THE YELLOWSTONE NATIONAL PARK.

The Northern Pacific Railway was completed by the construction company connecting the unfinished ends this week, and the formal opening of the traffic is now awaiting President Villard's ceremony of "driving the golden spike," early in September, and his official opening of the line which runs for 1,919 miles across the continent, between the Lakes and Mississippi on one hand and the Pacific Ocean on the other. [The last spike has driven September 8, 1883.] This road with its branch southward into Wyoming Territory will give comparatively easy access to the "wonderland" of the Yellowstone National Park, about five days' steady railway journey from Philadelphia. We have come to this Park over the new Northern Pacific line, crossing the prairies and "Bad Lands" of Dakota, and then running for 300 miles up the attractive but thinly populated valley of the Yellowstone River, and have passed through sundry frontier towns of large pretensions and unlimited future prospects, but of small present population. These were St. Paul and Minneapolis, monopolizing the milling interest of the Northwest, and each claiming to have 90,000 to 100,000 population. The Falls of St. Anthony, the greatest water power in the world, having the Mississippi River to supply it, gives Minneapolis the "boom" that leads its people to ask for building lots prices rivaling those of Philadelphia and New York, while its great mills were turning out 25,000 barrels of the finest flour daily. We went through the greatest flour mill in the world, the Pillsbury Mill, worked throughout by machinery from the time the car load of wheat enters it to be emptied by steam shovels, until the flour barrel is packed by machinery. This mill makes 5,300 barrels of flour daily, and cost $900,000 to construct. We viewed the gentle beauties of the great watering place of the Northwest, "Lake Minnetonka," in Minnesota, midway between the oceans, where there is a hotel, 700 feet long, and so constructed upon a peninsula between two arms of the lake that the builder has accomplished the result long sought by landlords—every room is a "front room." The waters of this lake go into the Mississippi, and on their way there flow over Longfellow's immortalized "Falls of Minnehaha." We traversed the great wheat fields of the "New Northwest" in Minnesota and Dakota, and visited the biggest farm in America, the "Dalrymple Farm," in the valley of the Red River of the North, where they were gathering a crop of 600,000 bushels on a wheat field of 30,000 acres, and employed 150 men, 500 horses, and 200 combined reaping and binding machines in doing the work; and when the reaping was finished they expected to set thirty steam thrashers at work to thrash it out, each of them given power by burning the straw of the crop, and each turning out a thousand bushels as a day's work. We passed over the extraordinary formation of the "bad lands," where underlying coal and lignite have caught fire and burnt the superimposed clay until it became brick, and then some convulsion of nature came along, smashed it into fragments of broken bricks and terra cotta, and piled it up with other debris, sand, and lava, in the conical and pyramidal forms known as "buttes," the most remarkable being the famous "Sentinel Butte," standing as a landmark on the dividing line between Dakota and Montana, where General Custer made his last camp before he and his force were massacred. We passed over the valleys of Montana, along the Yellowstone, where the short, rich buffalo grass makes the cattle ranches so profitable. We got among the Indians and found them much like other men, driving sharp bargains for trinkets and anxious for whisky and tobacco. We went through a succession of ambitious frontier towns of quick, mushroom growth, with rough border populations and a large supply of liquor saloons and gambling shops, the latter generally being licensed by the town authorities, and carrying on their business openly, with the "chips," money, and revolvers of the gamesters lying together on the tables. As As we journeyed westward we gradually lost the familiar minor coinage of the eastern cities—the cent—then the half dime, and then the dime, and found prices advanced 100 or 200 per cent. Every town asked exorbitant prices for its "corner lots," and had its daily newspaper to expand its "boom." As the Northern Pacific railway progressed westward, these mushroom cities have sprung up all along its line, which is laid out upon lands that a few years ago were the hunting ground of the Sioux. There is Miles City on the Yellowstone, the location of numerous lynchings; Billing's, covering—on paper—about three square miles, with streets numbered from Front to Thirty-fifth Street, and a population of 800, an ambitious city with an "opera house" and "Board of Trade;" and Livingston, 1,080 miles west of the Mississippi River, at the entrance of the pass leading into the Yellowstone Park, a town four months old, with 1,500 people, and two daily newspapers (price ten cents), and "eligible corner lots," 25 feet front, for sale at $2,000 each. The three national banks at Livingston drive a prosperous trade at lending money for two to three per cent. a month. The railway here is very near; the distances great between the towns, and the population sparse, everybody going armed, and the men being largely in the majority.

From Livingston we went southwest, through the lower cañons of the Yellowstone, into the heart of the Rocky Mountains, driving from the end of the unfinished railway over dusty, hilly roads, and among mountain ridges, some twenty miles, under a scorching sun, to the Mammoth Hot Springs, just within the Park. The hotel, like everything else in this country, is incomplete, for the Yellowstone region is old geologically, but new as a resort for tourists. The Park is in the northwestern corner of Wyoming Territory, and covers a surface of 65 miles north and south by 55 miles wide, of evident volcanic origin, and containing more natural curiosities than an equal area in any other part of the world; while within it are the sources of the greatest rivers of North America—the Yellowstone, Gardiner, and Madison, which form the Missouri, seeking the Atlantic; the Snake River, one of the upper waters of the Columbia, of Oregon, and the Green River, a branch of the Colorado, flowing into the Gulf of California. All of this region has at least six thousand feet elevation above the sea, while some of the peaks around it rise nearly 12,000 feet, and are covered with snow. Its Yellowstone Lake is the most elevated sheet of water of its size in the world, at 7,788 feet altitude, and covering 300 square miles surface. Out of this pretty lake flows the Yellowstone River, through the Grand Cañon, whose almost perpendicular sides, not over 300 to 500 yards apart, rise 1,000 feet and are brilliantly colored; and the gorge, which is so steep that no one can descend into it, continues for twenty miles. You creep to the edge and look down this extraordinary place, into which the river tumbles over a beautiful fall 360 feet high. Then there are hot springs and geysers of vast extent and limitless volume of power, surpassing anything elsewhere known. At least 5,000 of these hot springs have been found, depositing either lime or silica and making the most beautiful colors and ornamentation in their deposits; while at least fifty of the geysers throw water columns 50 to 200 feet. The most of these geysers are coy and bashful, not exploding and spouting excepting at irregular intervals, and you may watch them for days together without the waters being turned on; but the favorite, and one of the most beautiful, is the "Old Faithful," sending up its enormous column of water, from which dense clouds of steam are blown at regular intervals of about sixty-four minutes. Then there are the "paint-pots" and the "wash-tubs," the former being "mud geysers," where the different colored muds mixed up with water and steam keep up a constant commotion, and the latter making one of the most curious developments of this strange region. The "wash-tubs" are basins hollowed out of the deposits, and each has an aperture in the bottom. Through this hot water comes, and in the tub you can wash your clothes, but great carefulness is necessary, for in a twinkling, without notice, all the water will run out of the bottom of the tub, and if you are not quick enough to catch them the clothes will disappear also. The next time the water comes in, it may bring back the clothes or it may not; these geysers are very fickle about it. This extraordinary region has been known for the past three-quarters of a century. About 1807 a frontiersman named Coulter came in here, and when he returned to civilization he told such wondrous stories about the doings of those hot springs, wash-tubs, and geysers, that the borderers gave the place the name of "Coulter's Hell." Others visited it afterward and told similar tales, but were generally disbelieved. In 1869 a party of surveyors went through, but the first scientific exploration was by Professor Hayden's corps in 1871, his report leading Congress the next year to pass the law by which it was made a National Park and set aside as a pleasure ground for the people. Access, however, was difficult, and at the last session Congress passed the law by which the "Yellowstone Park Improvement Company" is authorized to build hotels for the accommodation of tourists, and to provide guides and transportation, their rates of charge being fixed by the government at a reasonably moderate tariff, considering the remoteness of the region and the long distances from which supplies must come. There are seven hotels to be built at the chief points of interest, and the first one, at the Mammoth Hot Springs, where the Park is entered, will probably be finished this year. The others will not be started till next year, when better accommodations for visitors will be provided than are now available.

The present hotel, where I am writing, has a strange location, being built upon one of the terraces of the Hot Springs formation, with the craters of extinct geysers, their cones, and yawning caves in the foreground view from the front windows. The terrace extends but a short distance, and then the ground sinks into the gorge through which the Gardiner River flows, with mountain peaks beyond, the highest, Mount Evarts, rising 7,600 feet. Lookout Hill is immediately in front, and on top of it is the house of the Government Superintendent of the Park, with the flag floating over it. The higher terraces of the Hot Springs, a white mass, streaked with brown, are on the right hand. The best idea the reader can get of this place is to conjure up the popular impression of the infernal regions, and provide a plentiful supply of heat and brimstone. For several square miles, rising from Gardiner River westward in successive terraces to the height of about a thousand feet above the valley, the ground is underlaid with internal fires, producing boiling water, steam, and sulphur, which make their way out to the surface in hundreds of places. The earth is cracked into fissures and every spark of vegetation is burnt up, while beneath can be heard the running water and hissing steam. From almost every opening hot water and steam escape; sulphur hangs in stalactites from the rocks, and in some parts the odors are almost overpowering. The Indians are said to have avoided this terrible place, and it is no wonder that the frightful tales told by its early explorers were disbelieved. Yet the scene is as beautiful as it is startling. Lakes and pools are framed by the hot springs with rim-like edges, over which the waters run, and trickle down upon terrace after terrace, forming the most beautiful shapes of columns, towers, and coral decorations from the lime deposits, and painting upon these delicious colors in red, yellow, pink, blue, and brown. So long as the water runs, nature continues this decoration; but as soon as the flow ceases and dries, the air turns everything white, and many of the more delicate formations crumble. The whole of this gorgeous structure has been built up by ages of steady and minute deposits made by the waters, the rate being estimated at about one-sixteenth of an inch in four days. An area of three square miles is occupied by these calcareous deposits, the more recent, on which the present springs are located, covering about 170 acres. The terraces extend two miles back from the river, there also being other separate patches of old deposits in the neighborhood that show the surface of the springs in earlier times to have been even more extensive than it now is. Some fourteen different terraces can be traced upward from the river bank to the highest formation. Two cones of extinct geysers rise from the terrace on which the hotel is built, the "Liberty Cap," 45 feet high, and a smaller and blunter formation called the "Devil's Thumb," which it is said to resemble. Both have been built up by the slow deposits from orifices still seen in their tops, but from which water long since ceased flowing. All the springs shift their locality as the deposits are made, so that the details of the scene steadily and slowly change.

In climbing about this remarkable place, the top of which is elevated about 6,500 feet above the sea, the effect of the rarefied air is quite apparent in the shortness of breath quickly arising from unusual exertion, but the effort is amply repaid. Some of the most beautiful forms and colors Nature ever produced are here disclosed. There is the "Orange Geyser," its sides streaked with orange, yellow, and red, from the little wavelets trickling down from the steaming spring at the top, which goes off at quick intervals like the exhaust of a steam engine. At the "Stalactite Cave" the flowing waters add green to the other colors, and also scale the rocks in places, like the back of a fish, while below hang stalactites with water dropping from them. The roof of the cave is small, but filled with beautiful formations. One of the finest displays is "Cleopatra's Bath," with "Cupid's Cave" beneath, the way to them being through "Antony's Gate," all built up of deposits. Here the finest possible coloring is painted on the rocks, while hot water and steam for the bath are in ample supply. The springs all form flat basins around the orifices, with turned up edges, over which the waters flow, and then, trickling down the front of the terrace, paint it. When the flow ceases and the dry air has burned the color white, it forms a spongy coral, pretty to look at, but crumbling under the touch. The currents run with a width of hundreds of feet over terrace after terrace, painting them all, and then seeking the Gardiner River. Everything over which the water flows gets coated by the deposit, which upon drying turns white, and people crawl round about in the hot water, hanging up bottles, jugs, and horseshoes to get them coated for curiosities. The most elaborate of the formations are the "Pulpit Terraces," a succession of magnificent structures fifty feet high, with finely colored columnar supports. We have a large pulpit, and in front on a lower level the font with water running over its edges. The pulpit was formed by a spring that has ceased flowing, so that it is now colored white; the font is streaked with red and brown. Finely-carved vases filled with water stand below, while alongside the pulpit there is an inclined surface, whitened and smoothed in wrinkles like drifted snow, requiring very little imagination to picture as a magnificent curtain. Beyond, a spring impregnated with arsenic is making a blackened border like a second curtain. In front of this fine display the surface is hot, cracked in

fissures, with steaming water running in bubbling springs through it and forming new pools in rim-bordered basins. Fish scales, gelatine and other formations are seen on the rocks and the water. It is impossible to describe this extraordinary region with its combination of basins and exquisite forms and colors. As we clambered about for hours, steam and sulphur almost stifled us at times, our feet got into the hot water, and we stumbled over the fissures, but every change disclosed new beauties. The hot springs extend all the way down to the river bank, and it is a common experiment of the angler to hook a small trout in the cold water of the river, and without changing position to then swing him still dangling on the hook over to the basin of one of these hot springs and cook him. The hottest temperature reached by the springs is 163° where the water comes out, but beneath the surface it must be at the boiling point, as steam is freely generated. The formation is wedge-shaped, running up into a gulch between the higher mountains that have pines scattered over them, and also bear some vegetation. The volume of these springs, close observers say, is annually diminishing, and every evidence indicates more violent forces at work in the past than now. There is quite enough, however, to satisfy any ordinary mortal in this reduced edition of the infernal regions, with their seductive beauties combined with fire and brimstone, 2400 miles northwest of Philadelphia. J. C.

Mammoth Hot Springs, Wyoming Territory, Aug. 25.

POWDER OF BEEF-BLOOD AS AN ALIMENTARY PRINCIPLE.

Our ideas of nourishing invalids with irritable and weak digestive powers have been somewhat revolutionized of late years by the remarkable results of Débove and Dujardin-Beaumetz with their methods of forced feeding; and they have clinically demonstrated that proper nourishment plays no unimportant part in the therapeutics of certain chronic and convalescent states. The indications for forced feeding are presented very frequently in practice, much more frequently, indeed, than many will allow.

Though the cases in which Dujardin-Beaumetz and Debove have obtained their best results have been phthisical, the splendid results obtained by Weir Mitchell and Playfair with systematic feeding show that its application is not limited to that class. Many cases of hysteria, anæmia, chlorosis, and convalescence from acute diseases and organic affections are accompanied by loss of appetite and even disgust for food; due in great part to the fact that the stomach has become so unaccustomed to the presence of food that it has partially lost its digestive power. the best restorative of which is food in small quantities frequently repeated. As the normal bulk of food cannot be retained or digested, the quantity must be decreased, while the nutritive value must be correspondingly increased. For this purpose we have the various meat-powders, etc., many of which are valuable, though in some cases none can be relished, or even retained, on account of their insipidity and, to some, slightly nauseous taste.

Excellent results have been obtained from the use of dried beef-blood. Recently Guerder, of Paris, has made an extensive trial of the dried beef-blood, made, however, by a new and improved process. Its advantages over powdered meat are: it is much cheaper, is superior to it in alimentary properties, representing seven times its own weight of fresh blood, and it exercises a more pronounced stimulant action on digestion and on the general organism. Whether this stimulant action is due to the extractive matters of the dried blood, to its salts, or to the large proportion of iron contained in it, cannot be positively stated. It is highly probable, however, that the iron constitutes an important factor, as its proportion of 0·30 part per 100 is sufficiently large to represent medicinal doses of iron.

It is quite certain that the reputed indigestibility of blood is without foundation, as the blood-bread in common use in Sweden is highly nutritious and easily digested, as are the blood-puddings eaten in other countries.

Debove and Dujardin-Beaumetz have not had good results from the use of dried blood. Guerder attributes this want of success to the large quantities which they administered, and their faulty methods of preparing it. Indeed, their results with his preparation have been eminently satisfactory. Guerder had administered it in 51 cases. Of this number 44 took it well, and without inconvenience, for several weeks. Three convalescents from typhoid fever were unable to retain it at all, while to the remaining 4, all chlorotics, it was disagreeable, producing unpleasant sensations in the stomach, and was sometimes vomited unchanged after several hours. While there is, of course, no fixed dose, we should be careful that the stomach is not imposed upon. A large spoonful may be given three or four times a day to children, with a little cold coffee, and two or more spoonfuls to adults. Pepsin may be added if it causes gastric disturbance. If the patient takes other food, the blood should be taken with it, preferably in a *cold* liquid, and, if necessary, disguised by some aromatic, as heat develops its peculiar taste and causes difficulty of absorption.

Although excellent results have been obtained from its use in chlorosis, convalescence from acute diseases, etc., effects upon phthisical patients have been most remarkable. When the disease was not far advanced there was invariably an early increase of strength, weight, and appetite. It is desirable that it be still further used, in order to determine, as nearly as possible, its exact value, and certainly, with Guerder's results, it is worth the trial.

Guerder's method of preparing the dried blood is as follows: Fresh beef-blood—sheep's blood is undesirable, having a very unpleasant odor—is defibrinated and cooked for five hours on a water-bath, then slowly dried in a current of warm air at a temperature of 104°–108° F. This demands at least three days, as every trace of moisture must be removed in order to prevent decomposition.

RAW EGGS FOR INVALIDS.

In this connection we may also speak of another article —highly nutritious, easily digested and retained, and but little used—viz., raw eggs. The only objection to their use is the individual objection of the patients. and this only before the first is taken, for they seldom object afterward. The egg may be broken into a glass, care being taken that the yelk is not broken, a little salt and pepper added, if desired, and the patient takes it. He scarcely has the trouble of swallowing, for it goes down of itself. We have seen patients retain easily and even relish a raw egg, who could retain nothing else, more than six hundred being taken in one case within three or four months. It goes without saying that the egg should always be carefully selected; and, indeed, for fear that one which has seen its best days should disgust the patient, it were better to prepare it out of his sight.—*Medical Record.*

PHOTOGRAPHY IN MEDICINE.

PHOTO-ELECTRIC APPARATUS.

Since the new gelatino-bromide of silver processes have come into use, photography has reached important results. Motion, which up to the present time has been considered an obstacle, is now no longer such, but, on the contrary, is sought for in order to give more life and reality to the subjects that we desire to reproduce; and we go even further than this, for we decompose it, we analyze it. The horse does not run with sufficient speed, and the bird does not fly fast enough to escape the apparatus of Messrs. Muybridge & Marey, whose interesting labors are now known to everybody.

In the presence of such results we need not be astonished to see that photography has entered into the domain of science in order to take an important place therein. In the present note it is our intention to point out to our readers the principal applications of photography in medicines.

Let us say in the first place that, at the present time, the majority of hospitals possess a photographic service. We record this fact with so much the more pleasure because this art, notwithstanding it is one of the finest applications of physics and chemistry, has been treated somewhat like a pariah. It is taking its place now in all laboratories in which precise records are desired, while waiting to enter further into courses of instruction.

One of these laboratories is particularly well known to us. It is that of the Salpêtrière, and is due to the initiative of our master, Prof. Charcot. We take it as a type, since it receives a certain class of diseases that require the use of special apparatus which we shall speak of further along.

On the day that he enters the hospital the patient is photographed. The photograph thus taken is to serve as an evidence and a control for observing all the transformations that may supervene in his state. In a case of hysterical *contractura*, for example, it is interesting not only to preserve the primitive form of it, but also to note with care its changes and oscillations. These different photographs are collected together in an album, so as to allow the entire series of phenomena that have occurred in a patient within a given time being seen at a glance. From a comparison of photographs taken from individuals afflicted with the same complaint, there will not fail to be obtained some interesting similarities. Prof. Charcot, in his clinical lectures in 1883 has particularly insisted upon this point apropos of *scleroderma*.

The new processes of photographic printing, which permit of any negative whatever being converted into a typographic plate, render such collections very valuable. In fact, these reproductions, joined with observations, theses, and medical publications, will be within the reach of all, to the great advantage of science and teaching.

It should not be forgotten either that positive photographs on glass, known as lantern slides, serve professors for putting constantly before their audience the subjects that form the object of their course. This teaching by the eyes, the value of which admits of no argument, is extending more and more, and it is due to photography that it has made so rapid progress. If the patient chances to die, the anatomist preserves the appearance of such deranged organs as may interest him, before preparing them for examination by the microscope.

Here enters one of the most important applications of photography; we refer to microphotography. We know and the histologist better than any one else, that those sections which we admire so much are subject to many causes of destruction. Some of them become altered, and others may be broken or got out of shape with the greatest facility. It therefore becomes necessary to preserve them, and photography permits us to do this, not only in a durable manner, but also so as to facilitate researches and studies. These sections will, in fact, be considerably enlarged, and then collected and published. There will no longer be any interest in shutting them up in laboratories, to the great detriment of all persons who are engaged with the subject of medicine.

Briefly stated, a photographic service especially conceived for the needs of medicine should possess, aside from the ordinary applications of photography, a microphotographic laboratory. The negatives and the glass slides for projections will be classed with perfect order, and albums containing photographs from nature, along with mcrographic enlargements, will be preserved, and contain all such indications as are of a nature to enlighten the physician who consults them.

This is now the role and the usage of photography. But this is not all. As we said in the beginning, photography decomposes motion. From this point of view, what finer field for study is there than medicine? If certain patients are incapable of stirring, how many others are there who are afflicted with an exuberance of motion? We mean, here, individuals who are affected with certain troubles of the nervous system, such as hystero-epilepsy, epilepsy properly so called, etc. The attacks that we have in view, far from being a singular mixture of inordinate motions, are submitted, on the contrary, to certain rules—to certain laws. If we take as a type a hystero-epileptic attack, we shall see, as has been proved and demonstrated by Prof. Charcot, that it consists of perfectly distinct periods, each of which permits of a succession of rhythmed and characteristic notions.

What we need, then, is an apparatus that shall allow of the following being done:

1. Of catching the different attitudes that are peculiar to the various periods.

2. In each period, of resolving a motion into a series of photographs taken within very short intervals of each other.

With this object in view, we arrange a series of objectives of the same focus in a circle upon a camera. Behind them we place a blackened aluminum disk, which has a rectangular aperture and is moved by clockwork. In a state of rest, the aperture just mentioned is situated in the interval between two of the objectives, and consequently the sensitized plate is protected from all luminous rays. A special catch is so controlled by an electro-magnet that, when a current passes, the aperture comes behind one of the objectives. The current being broken, the aperture moves again to the space between two other objectives, and the plate is masked anew, and so on.

The advantage of this arrangement is evident. So long as a current is passing, one of the objectives is in operation. Therefore, any length of exposure may be given, this being a necessary condition attending work in a laboratory. So long as the current is broken, the apparatus is closed. Therefore, the interval between two photographs may be graduated to within any limits.

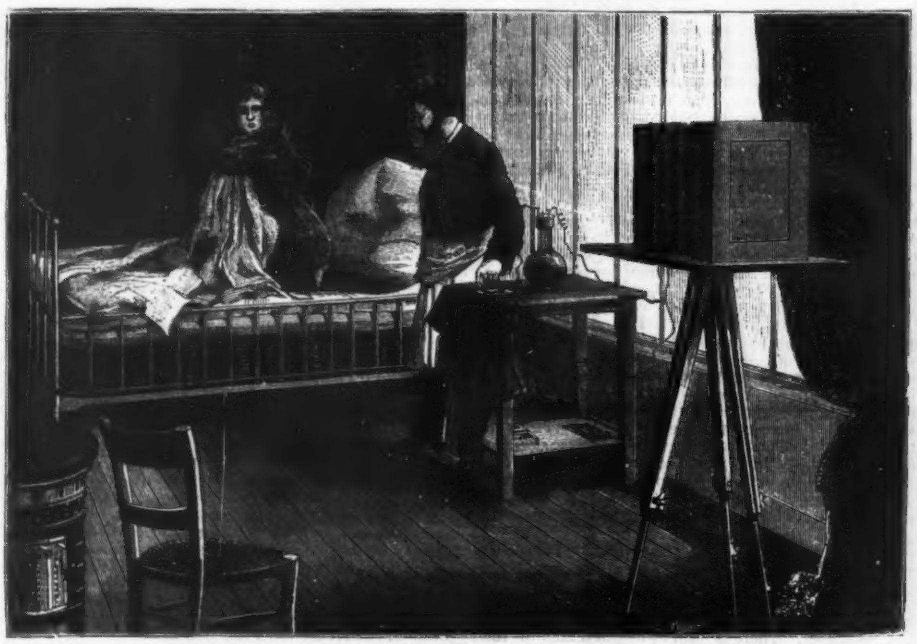


Fig. 1.—ARRANGEMENT OF PHOTO-ELECTRIC APPARATUS FOR MEDICAL STUDIES.

A needle placed externally follows the motions of the disk, and always shows the number of photographs that has been taken.

As electricity is the motor of the apparatus, the physician can operate from a distance, and while standing at the bedside of the patient. The general arrangement of the apparatus at the moment a negative is being taken is shown in the accompanying engraving (Fig. 1), where a physician, by sending an electric current by means of a Morse transmitter, is preserving the attitudes that he desires to study. It is with such an arrangement that photographs are obtained that characterize each period. When, in these periods, it is desired to decompose a motion, a Brequet manipulator is employed, or, better still, a transmitting cylinder that is given the necessary velocity by means of a regulator. This cylinder, which is made of an insulating material, carries a series of long metallic triangles set into its surface, and all of them communicating with one of the poles of the pile. During its revolution a metallic contact, which moves parallel with it, collects the current every time that one of the triangles is passing, and transmits it to the apparatus. Toward the extremity of the triangle the exposure will be very short, but the more the base is approached the longer it will be. It will be easily seen that with this method (being given a motion of known duration) it is easy to take photographs at variable intervals and with variable times of exposure. Motion that has been decomposed may be easily recompounded by means of the phenakistoscope.

Messrs. Muybridge and Marey were the first to take up this study of motion, the former by means of distinct apparatus placed in a row, and the latter by means of his photographic gun. For our own part we prefer the system of multiple objectives under consideration for the kind of studies that interests us. The expense as regards objectives is certainly greater, but the advantages to be gained make us waive such a consideration. The apparatus which we illustrate herewith is only a model, and is constructed so as to give images of a size to be used for projections. It is, moreover, essentially a laboratory apparatus, and may be constructed of any size.

One of its advantages is that it permits of obtaining more images within the same length of time. In fact, the disk may be given any velocity that may be desired. In the gun of our excellent colleague and friend, Prof. Marey, one rev-

olution of the barrel that carries the sensitized plate is obtained per second, and twelve photographs are taken, each with $\frac{1}{15}$ of a second exposure. All the intermediate attitudes between two photographs are lost. This is due, as well known, to the arrangement of the apparatus, this presenting the different parts of the same plate in front of a single objective, and allowing the light to enter only when the latter is immovable. It will be easily seen how much time is lost in the operation. In the system of multiple objectives, each of the latter is independent; and the time lost is considerably reduced, since the aperture in the disk always presents itself in front of an objective capable of operating properly. As the apparatus may be of any size, so the objectives may be of any number. Within the same length of time, therefore, any number whatever of photographs may be taken, it being merely a question of objectives.

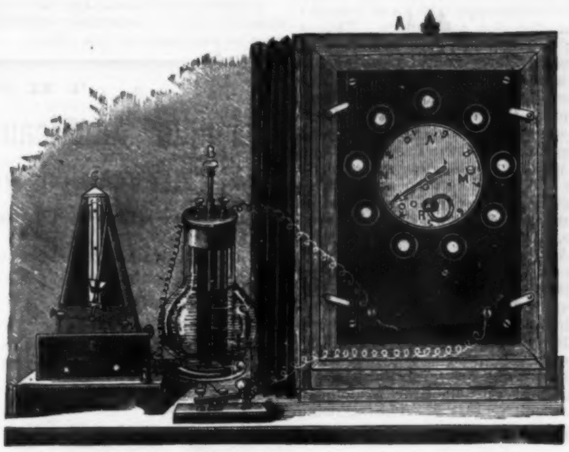


FIG. 2.—ARRANGEMENT OF APPARATUS FOR TAKING PHOTOGRAPHS AT REGULAR INTERVALS.

A. Photographic apparatus. B. Pile. C. Metronome. C'. Clockwork. R. Ring and arbor for winding. D. Morse transmitter. E. Reservoir of mercury.

We must refer, in conclusion, to one of the most convenient of apparatus for obtaining photographs at equal intervals, this being Mr. Gaiffe's electric metronome. The current coming from the pile enters this apparatus and makes its exit through an armature provided with two points that dip alternately, according to the motion of the metronome, into a reservoir filled with mercury. From this reservoir the current goes to the apparatus.

A Morse key is interposed into this circuit and cuts it, for the following reason: Everything being arranged, the metronome is regulated to the desired velocity by means of its slide, and, when it has reached its full speed, the key is depressed so as to allow the successive currents to pass until the needle has returned to its starting-point. The current is then broken and the operation is finished.

This apparatus, which we propose to call photo-electric, is well adapted for certain medical and physiological studies, and, in the art of war, might be conveniently employed in experiments with torpedoes. The force of these weapons, in fact, is studied by measuring the column of water that is lifted by their explosion, and the data that permit of obtaining this result are due to instantaneous photographs taken at equal intervals by different apparatus. In practice this arrangement gives rise to difficulties and errors that might be suppressed by employing the photo-electric apparatus, maneuvered at a distance and regulated in advance.—*Albert Londe, in La Nature.*

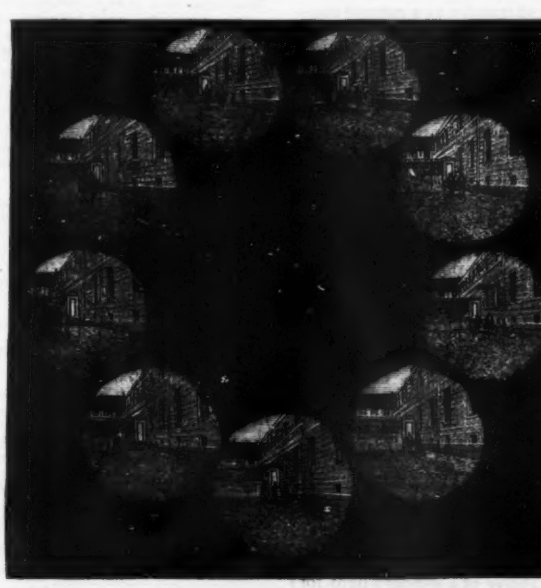


FIG. 3.—PHOTOGRAPHS TAKEN WITH SAME TIME OF EXPOSURE, BUT AT UNEQUAL INTERVALS.

THE deepest sea sounding ever made was in the Pacific Ocean in 1874, near the entrance to Behring's Sea. The depth was 4,655 fathoms, and the cast was made from the United States school ship Tuscarora. The shallowest water in the middle of the Atlantic—731 fathoms—shows the existence of submarine mountains 10,556 feet high.

FIBER PLANTS OF INDIA.

By J. W. MINCHIN, of Ootacamund, Madras Pres.

THE cultivation and treatment of fiber plants in India have occupied the attention of the Society of Arts on several occasions. The great botanist, Dr. Forbes Royle, first suggested the importance of the fiber-producing plants of India in 1854; and Dr. Forbes Watson, in an exhaustive paper before the Society, in 1860, enumerated the most important varieties; having, with the assistance of the Indian Government, collected specimens, and prepared plates representing them, which were published in the *Journal* of the Society (vol. viii., p. 448). Mr. Leonard Wray read a paper on Indian fibers in 1869, and it was again the subject of an article by Mr. P. L. Simmonds, in 1873.

Notwithstanding these frequent discussions, and the thorough knowledge that has been obtained of the value of the different principal Indian fibers, and of their cultivation and production, there has been no great commercial movement in the export of these fibers, and this is due to the difficulty that has been encountered in the treatment—the cost of preparing the fiber for the market by the native method of hand-scraping being prohibitive, and no machines or process for the economical preparation on a large scale having, until lately, been introduced.

For the valuable fibers strength and brightness of color are essential. The ordinary process of retting or fermentation in stagnant water cannot be followed.

The *Corchorus*, or jute fiber, is used principally for coarse bags, and such purposes where the strength and color of the fiber is not important. It can be produced at a very cheap cost; the cultivation of an acre of jute is estimated at Rs. 10 for the labor, and about half a ton of fiber is the usual crop; while by the retting process, one man can prepare for market about two cwt. of fiber in the day. The cultivation of jute has been taken up largely by the natives in India. The export, stated by Dr. Forbes Watson in his tables, in 1860, at 88,000,000 lb., had amounted in 1874 to 560,000,000, or seven-fold in the fourteen years. For the more valuable fibers this retting process is not available; a man can prepare only 5 lb. to 12 lb. of rhea or Manila hemp fiber in a day by hand-scraping, while the waste is enormous.

The necessity for some mechanical treatment has been long recognized. In 1872, the Government of India offered a reward of £5,000 for any machine that could separate rhea fiber in a green state, at a cost not exceeding £15 per ton. The conditions were not fulfilled, but a reward of £1,500 was given to Messrs. Greig, for relatively good results. The reward has since been withdrawn. The cultivation of rhea has now been successfully introduced into the South of France, Algeria, and the Southern States of America; and the attention of scientific men to some chemical or mechanical treatment has been continued.

There are now two machines and two processes that claim to treat green fiber successfully. This being accomplished, the golden hopes of Dr. Forbes Royle and of Dr. Forbes Watson, as to the future of Indian fiber, may be realized.

As the soil and climate of the hill districts of Southern India and Ceylon, with which I have been connected for the past twenty-five years, seem to me to be specially adapted to the cultivation of fiber plants, and as the introduction of any new industry is at the present time urgently wanted by the European planters settled in those portions of our Eastern empire, I have ventured to bring the subject forward again, for the purpose of urging the adaptability of this cultivation to the circumstances of the hill planters; and the fact that lately invented chemical and mechanical processes have supplied the economical and commercial prospects of success which have so long been desired.

The following fiber plants are suitable for cultivation in the hill districts of Southern India: Rhea (*Urtica utilis*), Neilgherry nettle (*Urtica heterophylla*)—these are dicotyledons, or exogenous plants, the fibers residing in their bark or bast; plantain (*Musa paradisiaca*), wild plantain, Manila hemp (*Musa textilia*), aloe (*Agave americana*), pine-apple (*Bromelia ananas*), wild pine-apple (*Bromelia sylvestris*), mooga, or bow-string hemp (*Sanseviera zeylanica*), mudar (or *Calatropis gigantea*)—which are monocotyledons, or endogenous plants, the fibers being embedded in the pulp of their roots, stems, and leaves. These and other kindred plants are indigenous to India, and can be cultivated without difficulty.

Rhea (*Urtica utilis*), *Boehmeria nivea ramia*—China grass—is a perennial plant. In China, fields of rhea are said to last, with care and manure, for 80 to 100 years. It grows in Sikkim and Nepaul at an altitude of 3,000 feet. It has been cultivated successfully on many coffee estates in India and Ceylon; but it requires rich, unexhausted soil. It grows with the greatest vigor in damp warm climates. In the islands of the Indian Archipelago it is cultivated under shade. It requires a light but fertile soil, but it must be well drained. It is propagated from the separated roots, from layers, slips, or cuttings; in this way five cuttings of grown stems can be expected in the year after planting; from seed, no crop can be expected before the third year.

M. Favier describes the plant as giving out several stems, of which the number increases in proportion to the development of the root, which forms a kind of tuft or bush. The stems are woody, and have the appearance of thick, strong rods, the height varying from 5 to 12 feet. The roots, slips, or layers should be planted 18 inches apart, and after the first crop the alternate rows should be transplanted into new fields, leaving the remainder, about 3,500 plants per acre, to spread and cover the ground. The yield in Java is said to be 44 stems per year from each stool, taken in four cuttings. Each stem in its green state weighs about 1 lb; 100 lb. weight of green stems yield 5 lb. of a raw fiber or filament, which, by Muspratt's analysis, as quoted by M. Favier, contains 66 per cent. of pure cellulose. In the official reports to the India Office, with native hand treatment the crop is said to be 1,000 lb. of raw fiber per acre, taken in four cuttings. M. Favier states that in Algeria, 1,400 lb. of fibrous thongs was the crop per acre, as calculated by Mr. Hardy, ex-Director of the Botanical Gardens there, while in the South of France as much as 1,600 lb. of filament have been obtained to the acre.

Mr. P. L. Simmonds, in his article in 1873 (*Journal*, vol. xxi., p. 762), stated that the crop gathered in Jamaica amounted to 300 lb. per acre at each cutting, and that there had been five cuttings in the year, making the yield three-fourths of a ton per acre per year. While Mr. Bainbridge, in the discussion on Mr. L. Wray's paper, in 1869, stated that the result of his own experience in Assam was 750 lb. green nettles, which gave 45 lb. weight of fiber in each of three cuttings, making only 135 lb. per acre per year (*Journal*, vol. xix., p. 453). The yield appears to depend on soil, climate, and treatment. The properties of the rhea fiber place it in the first position among vegetable fibers; it is second to none in strength, while the fineness or attenuation of the fiber places it before flax, and it is equaled only by the pine-apple fiber. It can be used for any textile purpose, having been mixed with cotton, wool, and silk to advantage; it is in special demand for sailcloth, table napery, curtains, and tapestry; but from the very limited supply as yet available, the applications of this beautiful fiber are yet in their infancy.

Neilgherry nettle (*Urtica heterophylla*) is an annual, and can be readily grown from seed, giving its crop in about seven months. It gives a strong, white, glossy fiber, and a sample, hand cleaned, was valued at £125 per ton. The cultivation has not been tried on a commercial scale; the difficulty will be in the cultivation and collection of the crop, as the leaves and stem are armed with a most poisonous sting. It has occupied the attention of planters on the hills for many years past, but no means of treatment was known.

Plantain (*Musa paradisiaca*) is generally cultivated for its fruit; it should be planted about six feet apart, and each stem will give about 4 lb. of raw fiber, and 50 lb. of fruit per year. The fiber is fine, white, and silky; long, light, and strong. The quality depends on the mode of cultivation and treatment; but it is not so valuable as Manila hemp. The Government of India have constantly urged the value of this material for paper making; but no use has ever been made of the millions of trees grown in India for their fruit. The stems are cut down and left after the fruit is moved.

Manila hemp (*Musa sylvestris*) has been successfully grown in Wynaad and other hill districts, since 1864; but hitherto to no commercial value, from inability to treat the fiber. It is grown extensively in Manila, where 250,000 acres are planted with this staple; it has hitherto been treated only by hand, the natives preparing about 12 lb. weight of fiber per day, and receiving one-half its value for the work, the waste being so great that only about 1 lb. of fiber is obtained from each tree. Yet, notwithstanding this, the exports have amounted to 35.000 tons annually. Manila hemp is imported into Europe and America for rope making only, and is worth £20 to £60 per ton, according to quality; the crop may be taken at from 10 cwt. to 2 tons per acre, according to successful treatment.

Aloe (*Agave americana*) will thrive on any sterile, waste land, and is now common throughout India. The cultivation is being extensively carried on in Mexico, where 5,000 plants may be found in an acre. It comes to full growth in three years, and can easily be propagated from suckers. The fiber is principally used for mixture with Manila hemp in the manufacture of cordage, and is worth about £10 per ton less than Manila hemp

Pine apple (*Bromelia ananas*) and *Bromelia sylvestris* produce a very valuable fiber. The former is cultivated for its fruit in all coffee estates, and the latter is found in large

quantities in all the jungle swamps in the hill districts. The fiber is valued at £45 to £55 per ton.

Bow-string hemp (*Sansevieria zeylanica*) can be propagated on almost any soil, from the slips which issue in great abundance from the roots; it is perennial; the wild leaves are from 12 to 16 inches long, but under cultivation attain 3 to 4 feet. Dr. Roxburgh estimated that an acre of land would produce three-quarters of a ton of clean fiber.

Mudar tam. zercum (*Calatropis gigantea*) is common on all waste places in India. Mr. G. W. Strettel, of the Indian Forest Department, in his pamphlet, "A New Source of Revenue for India," published in 1878, urges the value of this product on the attention of the Indian Government. It comes to maturity in a year, is perennial, and requires no care. Mr. Strettel estimates the cost of bringing an acre into cultivation, planting 4 feet apart, at £3 9s. 8d., after which the only recurring expense would be for harvesting and treatment. He estimates that it will yield a crop of from 5 to 7 cwt. per acre yearly, and the fiber is pronounced equal to good flax, and therefore worth £40 to £50 per ton.

The treatment of green fiber has now been successfully accomplished by the following machines and processes:

1. The machine of Messrs. Death & Ellwood, of which over one thousand are now in use, for extracting fiber from all kinds of aloe, plantain, and pine apple, etc., in Mauritius, Canary Islands, Africa, etc. It is almost the only machine in use for extracting Henquin fiber or Sisal hemp, and Ixtle or wild pine apple fiber, in Central America, of which 17,000,000 lb. weight are now exported annually. It is being tried in Manila for the treatment of Manila hemp. The jet of water which acts as an elastic cushion on which the fiber is beaten to clear it of boon and useless particles, acting also most satisfactorily in removing the gummy matter which causes the principal difficulty in the treatment.

2. An ingenious invention of M. Roquet, a Frenchman, for crushing and scutching vegetable fibers at one operation, which has been patented by Mr. W. M. Adams in this country and elsewhere. It treats all kinds of dry fibers most thoroughly, and has also successfully treated green rhea fiber from Kew Gardens.

3. M. Favier, a Frenchman, has suggested a process of treatment for rhea fiber, by steaming the green stems in the field. This enables the easy decortication of the bast by cheap hand labor, at a very small expense, and saves the cost of carriage of the woody portion of the stems, these being used for the fuel of the boiler that creates the steam. The stem ashes can be at once returned to the field as manure, together with the leaves and waste, so that only the fiber itself is removed from the soil; by this process it is calculated that the fiber thongs can be obtained at a cost of 30s. per ton.

4. The process which is known as Ekman's patent, for the manufacture of cellulose or ultimate fiber from raw fibers, by treatment with the bisulphate of magnesia. This process consists in boiling the fibrous substance under a pressure of 90 lb. of steam, in water containing sulphurous acid in combination with sufficient magnesia to prevent the oxidation of the organic matter. This chemical treatment produces an ultimate fiber from the rhea plant, which is worth £168 per ton or three times the value of the best cotton.

Seeing that it takes 100 lb. of green rhea stems to make 5 lb. of raw fiber or filament, worth at the rate of £45 per ton in the English market. M. Favier's steaming process, which saves the carriage of the woody portion further than the field in which it is grown, is an economical consideration of the highest importance.

This raw fiber or filament, after treatment in M. Ekman's boilers, is reduced from 5 lb., worth at the rate of £45 per ton, to 3½ lb. of ultimate fiber, worth £168 per ton. When this process is undertaken by the grower in India, as soon as possible after cutting and decortication in the field, the fiber is saved from the damage that is constantly going on from fermentation, as long as the tannic gum is attached to it; it being impossible thoroughly to dry the fiber while this gum remains. There is no trouble in at once drying and packing the ultimate fiber. The cost of carriage to the manufacturing market is reduced to a minimum, and the pure fiber is in no way damaged by pressure in packing under screw or hydraulic press. At the same time the cultivator obtains the full manufacturing value, which is otherwise intercepted by the mill men, who scutch, comb, and prepare the fiber for textile uses.

It seems that for dicotyledons, or exogenous plants, such as rhea and Neilgherry nettle, M. Favier's steaming process, in conjunction with M. Ekman's bisulphate of magnesia process, have attained the desired object, economical and thorough treatment.

For the monocotyledons, or endogenous plants, such as plantain, Manila hemp, aloe, pine apple, etc., the machines of Messrs. Death & Ellwood or M. Roquet are required. For the coarser fiber obtained from these plants no further treatment is necessary; these coarser fibers are used for rope making. The finer fibers, such as those obtained from the *Bromelias*, and the selected finer portions from other kinds may be advantageously treated in M. Ekman's boilers; while from the waste and inferior stuffs a paper pulp may be obtained which will be an important item in the receipts of the estate. In the cultivation of the fiber plants I have enumerated, the planters on the hill districts of South India will have varieties suited to every exigence of their soil and climate. For their exhausted fields, which are no longer suited for the cultivation of coffee, cinchona, or tea, there is aloe, mudar, or moorga available, which will flourish on the poorest and most exposed hill sides. For their low lying rich valleys, at elevations too low for coffee or cinchona, such as the lower slopes of the Ghats, the cultivation of rhea fiber can be carried on; on the level land, where plowing is possible, the Neilgherry nettle can be sown to advantage. The undrained swamps can be planted with the *Bromelia sylvestris*, and the borders of the streams and steep forest hills can be cultivated with plantain and Manila hemp.

The store houses and water power generally found on the coffee estates that have been erected for the preparation of the coffee crops, and which are unused for nine months in the year, will supply the motive power for the scutching machinery, and drying accommodation for the fiber. It is probable that the cost of Ekman's boiling and chemical process may be too considerable for each individual planter, but some convenient central factory established in each district, or on the coast, may enable the planters to obtain the benefit of this process, on the same principle as is now in use for the ultimate preparation of their coffee. It therefore seems that good hope is afforded; that the cultivation of fiber plants may relieve the Indian and Ceylon coffee planters of much of the troubles that have befallen them, from the persistent attacks of the *Himeileia bastatrix*, or leaf disease.—*Journal of the Society of Arts.*

RESEARCHES ON THE IGNITION OF MIXTURES OF EXPLOSIVE GASES.

Mallard and Le Chatelier chose for the investigation of this subject mixtures of hydrogen and air, and of carbonic oxide and air.

(1) *Temperature of Ignition.*—To measure this point, they employed a porcelain pyrometer, which was heated in a Perrot furnace; it was employed alternately as a thermometer and as a chamber of explosion. With a three-way tap of glass, communication could be opened with an air pump on the one hand, and on the other with the tubes leading to the air or with the gases to be experimented on. In order to measure the temperature of the pyrometer, it is first pumped empty of air and then filled with air, and its volume is measured. From this it is easy to calculate the temperature. After this has happened, the instrument has again to be pumped empty, and the gaseous mixture is then allowed to enter, when one soon becomes convinced whether or no at the temperature an explosion took place. This is known, first, by the noise; and, secondly, by a change of volume, which most gaseous mixtures undergo during explosion. Here it is assumed that the temperature of the furnace remains constant for a certain time, which, indeed, is hard to arrive at. We must therefore make two determinations of temperature—one before the experiment, the other after—and take the mean of them. The results can only be regarded as sufficiently exact when the two temperatures, thus determined, are not exceedingly far apart. With each gaseous mixture a number of series of experiments were made at temperatures which were as little removed from each other as possible. One must lie above the temperature of ignition, the other below it. The results obtained in this manner were very accordant, as the following numbers obtained for the explosion of mixtures of hydrogen and oxygen will show: First series, 540 to 555 deg.; second series, 552 to 577 deg.; third series, 550 to 560 deg.; fourth series, 557 to 562 deg., fifth series, 539 to 552 deg.; sixth series, 552 to 557 deg.; seventh series, 552 to 559 deg. The temperature of ignition, therefore, of this mixture lay at 552 deg. In other experiments the authors have gone much further, and the work was much increased. The following determinations were made:

	Hydrogen.	
(1) Hydrogen and oxygen.	(0·15 O, 0·85 H)	560 to 570 deg.
" "	(0·30 O, 0·70 H)	552 " 569 "
" "	(0·66 O, 0·33 H)	530 " 582 "
(2) Hydrogen and air	(0·70 air, 0·30 H)	552 " 553 "
" "	(0·30 air, 0·70 H)	530 " 570 "
(3) Hydrogen, oxygen, and carbonic acid	(0·15 O, 0·35 H, 0·50 CO_2)	562 " 592 "
Hydrogen, oxygen, and carbonic acid	(0·21 O, 0·49 H, 0·30 CO_2)	560 " 595 "
	Carbonic oxide.	
(1) Carbonic oxide and oxygen	(0·15 O, 0·85 CO)	630 " 650 "
Carbonic oxide and oxygen	(0·30 O, 0·70 CO)	645 " 658 "
Carbonic oxide and oxygen	(0·70 O, 0·30 CO)	650 " 680 "
(2) Carbonic oxide and air	(0·70 air, 0·30 CO)	650 " 657 "
(3) Carbonic oxide, oxygen, and carbonic acid	(0·15 O, 0·35 CO, 0·50 CO_2)	685 " 715 "
(4) Carbonic oxide, air, & carbonic acid	(0·35 air, 0·15 O, 0·50 CO_2)	715 " 735 "
	Methane.	
Methane and oxygen	(0·70 O, 0·30 C_2H_4)	600 " 650 "
" "	(0·30 O, 0·70 C_2H_4)	640 " 660 "

The most remarkable result of these experiments is that the temperature of ignition of the gaseous mixture is little affected by the admixture of strange gases. The greatest variation occurs by the addition of carbonic acid to the carbonic oxide mixture; in the case of the hydrogen mixture the influence is less. From this we are driven to the assumption that the temperature of ignition of a gaseous mixture is affected by the products resulting from the explosion. In the case of mixtures of methane and air this method of investigation cannot be used, because the volume of the gas is not altered, and no such considerable explosion takes place that it can be observed outside the pyrometer. The authors therefore endeavored to determine the ignition point in this instance by passing the mixed gases through a porcelain tube in a furnace and placing an air thermometer as close as possible to it. The results of this experiment vary considerably—between 600 and 750 degrees. In any case, the point of ignition in this instance lies below 750 deg., and probably about 640 deg. This result shows that the assumption that the gas exploding in mines explodes at 1000 deg. cannot be maintained. It had already been shown by Davy that it is not possible to explode the mixture with a white hot rod, and he held that flame was absolutely necessary to accomplish it. The authors find that the mixture always explodes at about 800 deg. in a pyrometer after the lapse of some time, while hydrogen and oxygen always go at once. In Davy's experiment the heat of the rod caused a circulation of the gases, which hindered the continuous action of the high temperature on the gaseous mixture. If in place of the iron rod an inverted iron crucible be employed, ignition always takes place, even when the iron is only red hot, because the gas remains sufficiently long in contact with the hot metal in the hollow of the vessel. The authors point out the application of this fact to certain mining questions.—*The Engineer.*

THE STANDARD OF LIGHT.

A discussion respecting the choice of a standard light for photometrical purposes was recently held at a meeting of the French Societe d'Encouragement, when M. Felix Le Blanc, a member of the council, made a communication respecting the researches now being conducted on the subject. He observed that the candles generally used in England and Germany vary greatly in intensity, and are of comparatively feeble illuminating power; while the Carcel lamp used in France, although giving a very constant light, is not so powerful as might be desired for some purposes. The "Star" candles, manufactured in France, were formerly equivalent to one-seventh of a Carcel; but they have now fallen to one-eighth of a Carcel. M. Le Blanc valued the English standard candle at one ninth of a Carcel; with a variation of 14 or 15 per cent. between different samples. He also valued the German candle at one-sixth of a Carcel. M. Le Blanc considered, in view of the difficulties and chances of error attending the adoption of other standards, that the Carcel lamp is, on the whole, the best. The President of the Society, in commenting upon the preceding communication, remarked that the International Commission of Electricians sought a more powerful light than the Carcel; and that if this condition is to be deemed essential, platinum in the state of fusion is the only luminous source obtainable. A square centimeter of this metal, observed at the moment of solidification as proposed by M. Violle, gives the light of about 7 or 8 Carcels. Melted silver, upon which M. Violle at first experimented, gives a very feeble light, just sufficient to enable the fact to be noted that during the time of solidification heated metals emit light-rays of constant intensity. M. Peligot, Secretary of the Society, observed that the fabrication of the "Star" candles has been sensibly altered since their introduction, to the diminution of their luminous value. He also complained of the high cost of Carcel lamps, now that their manufacture has become a specialty; but, in reply, M. Le Blanc said that very good moderator lamps, specially constructed for photometrical use, could be obtained at a cheap rate.

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